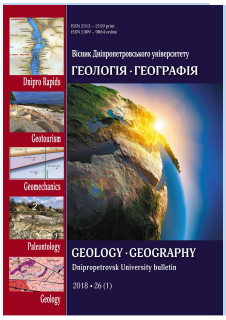

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Вплив умов рельєфу на ріст та розвиток рослин

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Анотація. Мета досліджень описати межі мінливості основних сільськогосподарських типів сучасних українських сортів пшениці озимої відповідно до їх взаємовідношень із різними умовами вирощування. Цільовими ознаками для визначення цих зв'язків були агрономічно-цінні, такі як урожайність, вміст білка та білкові компоненти (вміст гліадинів та глютенінів). Додатково оцінювали зв'язок між умовами рельєфу та вмістом мікроелементів та важких металів, зв'язок між умовами вирощування та вмістом цінних мікроелементів (азот, фосфор, калій). Наші дослідження підтвердили положення про зв'язок між умістом поживних речовин у рослинах пшениці озимої, їх надходженням із ґрунту, типом рельєфу, генотипом пшениці озимої та межами адаптивності в різних умовах. Пшениця озима проявила себе як культура з достатньо широкими, але разом із тим специфічними вимогами до умов росту та розвитку. Відносно до умов рельєфу, схили північної експозиції мають більше переваг для вегетації пшениці озимої. Ми рекомендуємо сорти Комерційна, Смуглянка, Золотоколоса для вирощування в таких умовах за зерновою продуктивністю та сорти Комерційна, Смуглянка, Золотоколоса за вмістом білка та співвідношенням білкових компонентів. Мінливість агрономічно-цінних ознак була більш високою в умовах схилів, ніж на рівнині. Тільки сорт Корисна був стабільним у прояві ознаки композиції білків у будь-яких умовах. У той же час для досягнення більш високого рівня зернової продуктивності всі сорти сильно залежали від умов вирощування (рельєф). Щодо якості зерна такої залежності не спостерігалось. Ми встановили, що зерно пшениці містить більш високу кількість мікроелементів, ніж солома. В той же час у солому в суттєво більшій кількості надходять свинець та нікель. Таким чином, вплив рельєфу на вміст мікроелементів та важких металів не такий високий, як для макроелементів та, через них, на зернову продуктивність та якість.

Ключові слова: рельєф, умови вирощування, озима пшениця.

Influence of relief conditions on plant growth and development

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Abstract. The objectives of our investigations are to describe the limits of variability of the main agricultural types of modern ukrainian winter wheat varieties in order to their relations with difference growth conditions. The most target traits for determining these relations are agronomic-value, such as yield, protein content and protein composition (amount of gliadins and glutenins). As an additional purpose we evaluated relations between relief conditions and amount of microelements and heavy metals, relation amid growth conditions and content of value microelements (nitrogen, phosphorus, potassium).

Our investigations confirmed statements about relations between content of nutrient elements in winter wheat plants, their uptaking from soil, type of relief, wheat variety genotype and limits of adaptable for difference conditions. Winter wheat is an cultivar with wide, but specific demands to growth and development conditions. Due to relief conditions, north exposition of the slope gives more advantages for winter wheat vegetation. We recommended varieties Komerciyna, Smuglyanka, Zolotokolosa for growing under these conditions by grain productivity and varieties Komerciyna, Smuglyanka and Natalka by grain protein content and protein composition. Variability of agriculture-value traits between varieties was higher under slope conditions than on flat. Only variety Korisna was stable by protein composition under every condition. At the same time all varieties were depended on grows conditions (relief) to reach high level of grain yield. We cannot observe just the same by grain quality. We established that wheat grains contains more microelements than straw. At the same time the lead and nickel uptake was more in the straw samples. Thus, influence of relief on microelements and heavy metals content in the winter wheat grain and straw is not so high as for macroelements and, thus, for grain productivity and quality.

Keywords: relief, landscape, winter wheat.

Introduction. With the annual production of about 757 million tons (in 2017) (USDA, 2018), bread wheat (Triticum aestivum L.) is one of the world's most important crops. Winter wheat is the world's leading cereal grain and the most important food crop, occupying commanding position in Ukraine Agriculture take 48% area under cereals and contributing 38% of the total food grain production in the country (Nazarenko, 2015). Until the end of the 19th century, cultivars were mainly landraces that were well suitable to their regional conditions. Since the beginning of the 20th century, as breeding methods have developed, landraces have been used as a source of variability in creating modern cultivars by classical breeding methods(Bordes et al, 2008). In the last 60 years intensive plant breeding programs led to the total replacement of landraces by modern semi-dwarf and high-yielding varieties, correlating with a decrease in wheat genetic diversity and needs in special requirements for realization their potential higher grain productivity and protein quality (Nazarenko and Izhboldin, 2017). This may have caused changes in the agrotechnology for winter wheat growing, consequently influencing on the future adaptability and special interactions with environment of this major crop (Milyutenko, T.B, 2011).

In the past wheat researches was more tried to improve grain productivity of the crop, but winter wheat breeders ignored the importance of wheat growth conditions on different reliefs. By conditions it means the relief of lands for cultivation and exposition of slopes land which determine the properties of wheat yield and the quality of grains (Dawson et al, 2011). These agricultural-value traits in interaction actually determine the overall varieties of wheat whether good or poor for farming (Gepts, Hancock, 2006). Winter wheat yield has the most important and complex character affected directly or indirectly by gens systems present in plant (Rangare et al, 2010) as well as interaction with environment (Tester and Langridge, 2010; Serpolay et al, 2011). This has been in response to the pressure for an adequate food supply caused by constantly increasing population in Ukraine and the world as a whole (Martynov and Dobrotvorskaya, 2006; Mba et al, 2012). Therefore, ecological estimation of new wheat varieties with high yield genetic potential under difference condition, it`s components (Slafer and Andrade, 1993) and quality traits (Sperling et all, 2001) has become a permanent purpose in the plant farming and breeding programs (Reif et al, 2005; Tuberosa and Salvi, 2006).

Disequilibrium in influence of different nature-agricultural factors and their interactions of region determine distinguishes in land using. High-level of lands tillage, complicated landscape and high amount of technical cultivars lead to soil degradation. Erosion of slope soils is one of the main components of this problem (Kharytonov et all, 2017). Due to this fact we investigated varieties requirements under different types of slopes. One of the main nature factors for evaluation is a land relief, content of macro- and microelements in the soils after erosion, plants and soil interactions, climate and hydrometeorology conditions, mutual influence between wheat plants and type of relief. They determined balance of moisture, character of winter wheat growth and development, differences in seasons conditions, intensively of water erosion (Andrusevich et al, 2018).

On the other hand winter wheat is the main stable crop for our country and in worldwide and globally provides more than 20% of calories and proteins in the human nutrition. Focused on only yield traits we have to understand that any high yield has no sense without proper quality for food and fodder demands. In mature grain, 10–15% of the dry mass is protein. Grain storage proteins (mostly gliadins and glutenins) include about 60–80% of the total protein in wheat grains and metabolic proteins, remaining part consists of the albumins and globulins (15–20%) (Dai et al, 2015). Grain storage proteins actively produce by plants during the effective filling phase of plant development (Shewry et al., 2012). The two main grain storage proteins fractions are glutenins and gliadins in mix together with water perform the rheological and bread-making qualities of wheat dough. These proteins, more certainly, are mainly responsible for the viscoelastic qualities of dough (Bonnot et al, 2017). Thus, the grain storage proteins components of wheat determines its economics value.

For proper protein complex formation we need in availability of N and S in the soil, which highly influences on quality and quantity characteristics. N supply increases the rate and duration of protein accumulation and so increases the proportion of S-poor grain storage proteins in mature grain (Tribo et al., 2003; Chope et al., 2014). Due to this reason one of the priority for winter wheat breeders is to enhance grain yield with reducing the requirements in fertilizers, especially nitrogen. There is a strongly negative correlation between grain yield and grain protein concentration traits, so increasing grain yield is generally detrimental to grain protein concentration and hence grain quality (Slafer and Andrade, 1993; Oury and Godin, 2007).

The objectives of our investigations are to describe the phenotypic variation of the main groups of modern winter wheat varieties due to their interactions with environmental conditions. The most target traits for developing these relations are once, which determining wheat quality and yield. Second our purpose to estimate asset of winter wheat accessions and appear a useful diversity in comparison of modern varieties. To appreciate the interest of researches in the vast geographical representation of wheat varieties, we compared the diversity of several directions of winter wheat breeding in Ukraine from difference regions of the country with great discrepancy in natural conditions and selection purposes in breeding process. All varieties in our investigation were harvested in a location suited to growing wheat, recommended to North Steppe district as suitable for agriculture in this region. Main agronomic-value traits were determined and analyzed.

Material and methods. Experiments were carried out on the experimental fields of Dnipropetrovsk State Agrarian and Economic University. The field`s geographic coordinates are: 48°30'N lat. and 35°15' E long. The experimental field is lied on 245 meters above the sea level. The air temperature during winter wheat growing season (September - July) is 8 - 11 °C, the average rainfall is about 350 - 550 mm in similar vegetation season. The field station of Dnipropetrovsk State Agrarian and Economic University use for many years (start from 60^{th} years of twenty century) as an area for intensive agricultural farming and researchs (Kharytonov et.al, 2017). It is located far away from the city Dnepro (about 30 km) enough to avoid industrial or town airpollution effects. The research fields occupies an area of 60 hectares and it is crossed out three types of landscapes. One of them is of 30 m. depth with a slope of > 7°, the other two have the slopes up to 3° Comparison of the received information in aspects of the crop yield and quality due to the landscape peculiarities gives us the incentive to classify the agricultural resource potential for different type of relief. Investigation was performed on flat (full-height normal soil), on the northern exposition slope (low eroded soil), on the southern exposure slope (middle level of erosion). Special attention was paid to the distinguishes with several traits (grain yield, weight of straw, protein and main protein components content in grains, assimilation of main macro- and microelements).

Winter wheat seeds were procured form department of breeding and seed farming of DSAEU. The recommended intensive agronomic practice was followed. Evaluation of total grain yield per plot was calculated from 2015 to 2017 years. The trial was set up at a randomized block design method with three replications and with a plot size of 20 m^2 in 3 replications (Bhutta et al, 2005).

The nitrogen and phosphorus concentration in plant samples was estimated using Kjeldahl method. Total P concentrations of the applied residues were determined by sulfuric acid digestion (Thomas et al., 1967). Potassium was determined with flame photometry. Trace elements were determined with method of atomic absorption spectrophotometry.

The protein content and contents of gliadin and glutenin were identified on devices of GDES INRA (Clermont-Ferrand, France) CNS Model Flash EA 1112 (for protein content) and RP-HPLS (for gliadins and glutenins) according to inside modified protocols of INRA.

Mathematical processing of the results was performed by the method of analysis of variance, the variability of the mean difference was evaluated by Student's t-test, factor analyses was conducted by module ANOVA. In all cases standard tools of the program Statistica 8.0 were used.

Results and discussion. As we can see from the tables 1 and 2 winter wheat was responded with statistics reliability on growth condition (relief of farming territory), which detected in yield and utilization of main nutrient elements from soil. Efficiency in utilization of mineral macroelements are depended on next factors, such as variety ($F= 44,20$; $F_{critical}= 4,04$: p-level 0,01), type of landscape($F= 62,36$; $F_{critical}= 5,11$: p-level 0,01) and quantity of mineral sources ($F= 12,10$; $F_{critical}= 3,98$: p-level 0,02) enabled for plants exploited. Regarding to our dates from the table 1 higher grain yield winter wheat was produced on slope of north exposition, especially for varieties Komerciyna, Smuglyanka, Zolotokolosa. All of these varieties are corresponded to intensive type, which required higher level of nitrogen fertilization than extensive type (such as Podolyanka in our investigations).

After analyze of peculiarities of macroelements (table 1) losses with winter wheat plants and quantities which requested for obtaining 1 ton of grain had been conducted we determined that demands of main nutrient elements are directly depended on winter wheat varieties special abilities in high grain yield performance. Nitrogen utilization by winter wheat plants on flat interfluves waved from 19,5 to 197,6 kg/ha, phosphorus 45,4 – 56,2 kg/ha, potassium 113,4 -137,2 kg/ha during three years. We can see difference in demands for different elements dependents on winter wheat varieties peculiarities. Some of the varieties need more nitrogen, but some need more phosphorus for grains formation. On the north exposition slope difference in grain productivity amid varieties is not so reliable that on the flat. The nitrogen losses from soil with yield were 173,9-190,1 kg/ha, phosphorus 48,6 - 68,0 kg/ha, potassium 132,8 -154,4 kg/ha. Mineral elements loses from soil with yield on south exposition were considerably less: nitrogen was 114,5-144,7 kg/ha, phosphorus was 36,7 – 45,4 kg/ha, potassium was 92,9 -112,3 kg/ha.

As we can found from the table 1 we can see twinter wheat require considerably quantity of nitrogen for producing 1 ton of grain 30,1-35,8 kg. This variation is explained with genotype difference of varieties. Donetskaya 48 carried out 35,8 кg of nitrogen while Natalka 30,1 kg for 1 ton of grain. On the other way variety Zolotokolosa with less expenditure in nitrogen (31,5 kg) under flat conditions gave us great yield than Donetskaya 48. Losses of phosphorus for wheat growth waved from 7,9 to 10,7 kg under flat conditions. Least was for variety Donetskaya 48 and peak for Korisna. The potassium uptake varied in limits 23,0-25,7 kg and fewer variables. Under north exposition slope conditions short-stem varieties Smuglyanka, Zolotokolosa got least demands in nitrogen (31,0 kg). The most demand were characterized for Korisna (35,1 kg) and Natalka (34,5 kg).

According to requirements in phosphorus variety Korisna was first (12,6 kg), Natalka was last (9,1 kg). Relate between potassium expenditure and variety was the like as in nitrogen. Demand in one was lowest for Smuglyanka and Zolotokolosa (22,7). Peak demand in nitrogen was 25,8-26,0 kg. Winter wheat on north exposition slope expended 28,0-33,0 kg of nitrogen, 8,5-11,1 kg of phosphorus and 23,3-27,2 kg of potassium for 1 ton of grain depending on variety.

Table 1. Yield and utilization of main nutrient macroelements by winter wheat plants.

Variety	Yield, t/he	Uptake from soil kg/he			For 1 ton of grain, kg		
		N	P	K	N	P	K
Flat							
Komerciyna	5,3	184,7	56,2	136,1	34,9	10,6	25,7
Korisna	5,1	159,8	55,1	128,5	31,2	10,7	25,0
Smuglyanka	5,9	197,6	54,0	137,2	33,6	9,2	23,3
Donetskaya 48	4,6	164,2	45,4	113,4	35,8	9,9	24,7
Natalka	5,3	158,8	50,8	135,0	30,1	9,6	25,6
Podolyanka	5,0	155,5	47,5	121,0	31,4	9,6	24,4
Zolotokolosa	5,6	175,0	54,0	127,4	31,5	9,7	23,0
Average	5,2	170,8	51,8	128,4	32,6	9,9	24,5
Slope of noth exposition							
Komerciyna	6,0	190,1	61,6	154,4	31,9	10,3	26,0
Korisna	5,3	185,8	68,0	136,1	35,1	12,9	25,7
Smuglyanka	6,0	185,8	62,6	136,1	31,0	10,5	22,7
Donetskaya 48	5,3	183,6	54,0	132,8	34,3	10,1	24,8
Natalka	5,3	183,6	48,6	137,2	34,5	9,1	25,8
Podolyanka	5,4	173,9	56,2	135,0	32,3	10,4	25,1
Zolotokolosa	5,9	182,5	59,4	133,9	31,0	10,1	22,8
Average	5,6	183,6	58,6	137,9	32,9	10,5	24,7
Slope of south exposition							
Komerciyna	4,4	144,7	42,1	112,3	32,8	9,5	25,4
Korisna	3,8	114,5	40,0	104,8	29,8	10,4	27,2
Smuglyanka	4,0	131,8	44,3	92,9	33,1	11,1	23,3
Donetskaya 48	3,9	119,9	36,7	100,4	30,4	9,3	25,5
Natalka	3,9	123,1	40,0	99,4	31,6	10,2	25,5
Podolyanka	3,9	127,4	37,8	104,8	32,5	9,6	26,7
Zolotokolosa	4,5	127,4	45,4	111,2	28,0	10,0	24,5
Average	4,1	127,0	40,9	103,7	31,2	10,0	25,4

Generally, dates at table 1 shows as that more productive varieties sometimes took from soil more total nitrogen and phosphorus spent less for producing 1 ton of grains (for example couple Smuglyanka - Donetskaya 48). As for our opinion its depends on the genotype peculiars in nitrogen utilization, intensive short stem varieties are more efficiency. Slope of north exposition was more preferable by growth conditions and gave a possibility to produce higher yield. Grain productivity of intensive genotypes more depends from relief conditions them extensive and under conditions of south slope difference was not statistically significance.

Assaying average uptake of nutrient substances from soil we are able to conclude about joint influence on this parameter either slope exposition and variety features (table 2). We can conclude that more measured quantity of nutrient elements in slope of south exposition winter wheat plant exploited at higher level than other. It has been shown us wide limits in winter wheat adaptation.

Table 2. Coefficient of nutrient elements utilization from soil on different types of relief, %.

Variety	Flat			Slope of north exposition			Slope of south exposition		
	N	P	K	N	P	K	N	P	K
Komerciyna	62,32	56,46	16,87	68,38	88,58	20,10	73,93	77,16	22,73
Korisna	53,93	55,35	15,96	66,86	87,77	17,68	68,58	73,23	21,21
Smuglyanka	66,76	54,34	15,96	66,86	90,09	17,68	67,37	81,10	18,79
Donetskaya 48	55,45	45,65	14,04	66,05	77,67	17,27	61,21	87,57	20,30
Natalka	53,63	51,01	16,77	66,05	69,89	17,68	62,92	73,23	20,10
Podolyanka	52,52	47,77	14,95	62,52	80,80	17,57	65,15	69,29	21,21
Zolotokolosa	59,09	54,34	15,76	65,65	85,45	17,37	65,15	83,22	22,52
average	57,67	52,13	15,76	66,05	82,89	17,91	66,33	77,83	20,98

Results of general uptake of microelements calculation are at the tables 3 and 4. So, we can see that the grain of wheat contains more microelements than straw. At the same time the lead and nickel uptake was more in the straw samples. It was one of the natural mechanisms for avoiding concentration of unappreciable elements in reproductive organs of plants. We cannot observe statistically reliable influence of relief on microelements and heavy metals content. Dates were contradictory.

On the other hand we have to regard decreasing of some microelements (Zn, Mn, Fe) in straw on the slopes and valley floor. When we determined uptake of microelements from soil (table 4) with winter wheat yield we observed that meaningful quantity of iron (1994-6587 g/ha), zinc (1025-1380 g/ha), manganese (1157-2527 g/ha) take out with winter wheat and wasted out of the field.

Uptake of copper was 253-428 g/ha, lead 199-289 gr/he, nickel 140-343 g/ha. Losses of microelements on the south exposition slopes were considerably less than on flat interfluves and slope of north exposition.

Table 3. Uptake of microelements and heavy metals with winter wheat grains and straw under different relief conditions mg/kg

Relief element	Zn	Mn	Cu	Pb	Ni	Fe
Grain						
Flat	22,1	22,2	3,8	2,1	3,0	43,1
Slope of noth exposition	20,6	28,3	4,8	2,1	1,4	41,3
Slope of south exposition	23,9	23,4	4,1	2,1	2,4	31,2
Straw						
Flat interfluve	4,2	17,3	3,2	2.8	3,1	72,0
Slope of noth exposition	2,7	15,3	2,7	2.7	1,8	19,1
Slope of south exposition	1,8	5,3	2,3	2.5	1,0	16,1

Table 4. General uptake of microelements and heavy metals with yield under different relief conditions, g/ha.

Relief element	Fe	Zn	Mn	Cu	Ni	Pb
Flat interfluve	6587,4	1380,1	1533,0	383,8	343,2	262,1
Slope of noth exposition	3400,8	1279,2	2527,2	428,5	185,1	289,1
Slope of south exposition	1994,7	1025,4	1157,5	253,8	140,4	199,7
Average	3994,3	1228,2	1739,2	355,3	222,9	250,3
Cv, %	26,7	5,4	14,2	11,8	28,2	5,7

Table 5. Protein content in winter wheat grains depending on variety and relief, %

Variety	Flat			Slope of noth exposition			Slope of south exposition		
	protein	gliadin	glutenin	protein	gliadin	glutenin	protein	gliadin	glutenin
Komerciyna	14,91	0,024	0,78	14,09	0,019	0,74	14,45	0,018	0,70
Korisna	13,00	0,037	0,66	13,64	0,032	0,69	13,18	0,035	0,77
Smuglyanka	14,36	0,034	0,66	14,73	0,029	0,63	14,50	0,027	0,60
Donetskaya 48	13,82	0,023	0,58	13,91	0,019	0,54	13,09	0,019	0,55
Natalka	14,45	0,024	0,73	14,45	0,019	0,68	14,73	0,022	0,80
Podolyanka	13,45	0,024	0,61	13,73	0,020	0,62	13,91	0,021	0,63
Zolotokolosa	13,64	0,023	0,60	13,00	0,019	0,57	13,36	0,020	0,59
Average	13,95	0,030	0,66	13,51	0,02	0,64	13,96	0,020	0,66
Cv, %	6.7	5,4	11,2	2.5	9,2	14,8	5,6	12,8	19,3

High protein content has been identified in grains of three varieties Komerciyna, Smuglyanka and Natalka. We cannot see great difference between relief conditions and we have to cocnclude it's depended only on genotype, not from the growth conditions in our investigations. Only variety Korisna has a good composition of protein under any conditions (and good quality of protein). Variety Smuglyanka has been identified by gliadins content and variety Komerciyna and Natalka by glutenins content. As we can see, they shows us the good amount or these protein components under any conitions.

Conclusion. Studies on winter wheat grain productive and quality traits are usually limited to a few types of landscapes and measured number of varieties (without any record of variety type by special demands for realized of potential yield). Here the overall diversity of seven varieties in terms of many important indicators of wheat grain productivity and quality (content of protein and main protein components) relating to growing, conditions was largely due to the diversity contributed by modern Ukrainian varieties. Further analyses are needed in providing evaluation under more types of reliefs and climate's conditions with wider number of varieties, which covered all types of varieties agrotechnologies. One of the key moment for further investigation is including determined of sulfur content in soil under different in our investigations, because the availability of sulfur in the soil highly influences on the grain storage proteins (gliadins and glutenins in our investigations) composition of winter wheat grain. The wide phenotypic variability for the most of the agricultural-value traits investigated is indicative of the large diversity of the varieties and genotype-environment interactions, mutual influences of landscape conditions and genotype peculiarities.

Finally, our investigations confirmed statement of relation between concentration of nutrient substances in plants, their loss from soil and peculiarities of relief, variety genotype and limits of adaptable. Winter wheat is an average culture by its requirements to growth conditions. Generally, north exposition gives winter wheat more preferable conditions for growth and development. We recommended varieties Komerciyna, Smuglyanka, Zolotokolosa for growing under these conditions by grain productivity and varieties Komerciyna, Smuglyanka and Natalka by grain protein content and protein composition (but in every case only for one of components. Variability of these traits between varieties was higher under slope conditions than on flat. Only variety Korisna was identified by good protein composition under every condition for both components. All genotypes were depended on grows conditions by grain yield on high level, but protein content and composition depended only on genotype. In addition, a useful variability for important traits in modern Ukrainian winter wheat varieties can be found in the different reactions on environmental conditions influence, illustrating the need to provide such investigations for improving some components of agrotechnologies for difference relief conditions, which not account up to now. Yield of intensive varieties more power related with growth conditions than extensive.

We established that wheat grains contains more microelements than straw. At the same time the lead and nickel uptake was more in the straw samples. Thereby, winter wheat plant has a teacher to avoid heavy metals in process of grains formation. The influence of relief on microelements and heavy metals content in the winter wheat grain and straw is not by far.

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