Agronomy Research **18**(3), 2103–2116, 2020
https://doi.org/10.15159/AR.20.187

Effect of winter wheat variety, hydrothermal coefficient (HTC) and thousand kernel weight (TKW) on protein content, grain and protein yield

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Abstract. The aim of the research is to clarify the physiological and biochemical processes in the plant organism that occur in the optimal and stressful conditions, as well as to search for anthropogenic methods of their manifestation in connection with the protein content in grain of wheat varieties of different origin in the conditions of the Forest-Steppe Ukraine. The impact of temperature factor and the moistening mode of the period of winter wheat seed formation and ripening (*Triticum aestivum* L.) has been studied. The impact of varieties of Ukrainian and foreign plant breeding on the protein content in grain of the obtained offspring (reproduction yield) has been studied too. The ways to eliminate the influence of weather conditions on the protein content in grain and on the bases of sowing of different seed fractions have been searched. Research methods: field (studying the influence of growing conditions on grain quality), laboratory (determination of protein content), correlation-regression (establishing connection between factors), statistical method (to confirm the difference between variants). According to the results of the first stage of research, the dependence has been established: sowing with seed, grown in the arid conditions, allows obtaining offspring with high protein content, and vice versa. This is confirmed by the strong correlation both for winter wheat variety. At the second stage of research it has been determined that sowing with fine seed raises the yield protein content in grain, and protein yield without additional costs, but using seed, formed in the arid conditions.

Key words: winter wheat, varieties, protein content in grain, air temperature, precipitation, seed size.

INTRODUCTION

In terms of harvested area *Triticum aestivum L.* and *Triticum turgidum ssp*. Durum are the most cultivated cereal in the world. Today, wheat cultivation accounting 220.11 million of hectares and 749.46 million tonnes (Falcone et al., 2019). Today, countries with the advanced agricultural production, in particular Ukraine, strive to increase the yield and quality of grain crops not expanding the sown areas. Winter wheat is the main grain crop in Ukraine. However, the level of yield and quality of grain remains low in comparison with European countries (Asseng et al., 2015).

Marenych et al. (2019) showed that the problem of increasing of yield crops (including winter wheat), can be solved by humic growth stimulators with keeping of soil fertility. Using of foliar crops fertilization with growth stimulant leads to improve plant nutrition conditions and increases the efficiency of mineral fertilizers. This is confirmed by our previous studies, which found that increasing of winter wheat yield is achieved by fertilizing of winter wheat crops (complex and microfertilizers). Also the influence of the average daily air temperature and the amount of precipitation during the spring-summer vegetation period and period of accumulation of nutrients in the grain on the winter wheat yield was established (Barabolia et al., 2018).

Protein and gluten content in winter wheat grain is a major indicator of its commercial and technological value (Asseng et al., 2018). Therefore, the price of grain in the world market is directly proportional to the value of these indicators. In this regard, improving the quality of grain is a pressing issue, which depends on the quality of bakery products and the selling price of products in the domestic and foreign markets.

The problem of protein content of winter wheat always encourages scientists to find ways to increase the protein content in winter wheat grain without additional agronomic measures and significant material resources. At the same time weather conditions significantly affected the process of triticale organogenesis at the early stages and yield (Mazurenko et al., 2020) and protein content is significantly affected by weather conditions, which are difficult to regulate. It is requiring more costs for increase protein content of winter wheat grain. The biochemical processes that take place in winter wheat plants under the influence of stressful weather conditions (high temperatures et al.) require more detailed study (Argentel-Martínez et al., 2019).

Recently agrarian variety policy has been aimed, first of all, at increasing the grain yields. Thus, the yields of grain crops and legumes in Ukraine in 1990–2018 varied in the range of 1.8 to 4.7 t ha^{-1} (Central Statistical Bureau of Ukraine, 2020). It has been determined that the increase of air temperature and the number of hot days will adversely affect the crop production, which is very difficult for world food security (Tripathi et al., 2016; Ruiz-Ramos et al., 2017). It has been established that the quality of winter wheat grain raised mainly in the hot favorable conditions. They are almost opposite to the conditions in which the high yields are obtained (Mondal et al., 2013; Iqbal et al., 2017; Ruiz-Ramos et al., 2017; Pandey et al., 2019).

Another, no less important problem is that the grain protein indicator is poorly inherited in generations, since it relates to the modification variability, which, in turn, largely depends on the certain weather and climate conditions (Ferris et al., 1998). That is why, while creating new varieties of winter wheat, breeders establish only the potential capabilities of this variety, which are realized depending on the environmental conditions (Dupont et al., 2006). It has been proved (Allen & Ingram, 2002; Almeselmani et al., 2009; Narayanan, 2018), that the violation of physiological and biochemical parameters in a plant, caused by high temperature or moisture deficit, is the weaker, the greater their resistance to these conditions. Hence, it can be concluded that the more drought-resistant variety, the weaker the biochemical processes violation will be under the lower values of the hydrothermal coefficient (HTC). Accordingly, there will be less possibility of the structural connections destruction and the hydrolysis of functional compounds. But, growth of the protein content in grain more than biologically optimal level is impossible without destruction and hydrolysis (Almeselmani et al., 2012; D'Amico et al., 2013). This suggests that the drought resistanse of a variety is a factor that reduces the ability of plant to respond to HTC decrease, and ultimately to increase the protein content in winter wheat grain.

Therefore, in our opinion, the deterioration of grain quality of modern winter wheat varieties is largely due to the selection of more drought-resistant and plastic varieties. The contrast of the optimal conditions for increasing yields, on the one hand, and grain quality improvement, on the other hand, result in the opposition of the processes that occur in a plant under the stressful weather and climatic conditions. In the optimal conditions of growth and development of winter wheat plants, prevailing mass of nodal roots is located in the upper soil layers. Due to soil drying (stressful conditions), they die off and their functions pass to the germinal roots, which, in search of moisture, develop a considerable mass, using carbon dioxide. As a result, the growth of aboveground mass is inhibited, grain yield decreases, and protein content increases.

Previous researches have established features regarding the physiological mechanism of protein content variability in winter wheat grain. It has been determined that due to the lack of moisture in the stress conditions the ratio of 'bound - free water' increases in a plant, whereas under the optimal conditions the opposite phenomenon is observed. In turn, the reduction of moisture in the soil almost to its dead reserve leads to the nodal roots dying off with a simultaneous intensive growth of the germinal ones. At the same time, with optimal moisture and nutrients supply, the intensity of their growth is almost absent. The genetic program of winter wheat is aimed at preserving itself as a species. Such preservation is based not only on the creation of offspring but also (and equally importantly) on the stable obtaining of viable seed, which can provide seedlings in any environmental conditions, within certain limits. Thus, in the optimal weather conditions, winter wheat grain which is more adapted to germination under the similar conditions is formed. The winter wheat grain, obtained under the stress conditions, better germinates in the dry conditions. This is the biochemical essence of protein content variability depending on the weather and climatic conditions (Sidorenko & Kulik, 2007).

Studying the issue of protein content in winter wheat grain, the authors (Zhemela et al., 2007) concluded that if the amplitude of fluctuations of protein content in grain under the influence of varieties, agrarian and technical measures varies from 9 to 14%, and under the influence of weather and climatic conditions varies from 9 to 24%. As grain protein is considerably dependent on the weather and climatic conditions (Chapman et al., 2012), maximum attention should be paid to this area of research. At the same time, we state that the inability to manage weather conditions necessitates their imitation. Changes in physiological and biochemical processes similar to the natural ones would take place in the plant under such imitation.

The problem of the impact of the temperature factor, precipitation and the combination of their influence of the winter wheat generative period on grain protein content remains to be fully clarified. The search for effective ways to decrease this effect on winter wheat plants and their ability to form high protein grain in the offspring without additional costs for its production is also of high priority.

The research results of foreign and Ukrainian authors indicate that improve the quality of wheat grain due to weather conditions is an actual problem today. Following issues (confirmed or disproved hypotheses) need to discovering:

1) will the 'encoded information' in seed (the amount of protein substances), formed in the arid, wet or optimal conditions, affect the formation of quality indicators of grain in the offspring?

2) is it possible to influence the offspring and to increase the protein content in it by selecting a certain fraction of the seed material?

Thus, the aim of the research is to clarify the physiological and biochemical processes in the plant organism that occur in the optimal and stressful conditions, as well as to search for anthropogenic methods of their manifestation in connection with the protein content in grain

MATERIALS AND METHODS

To study the response of winter wheat varieties of different origin to the weather conditions during the period of seed filling and formation on the variability of protein content in the obtained products (grain), we have conducted the relevant investigations.

The experiment was carried out in the fields of the training and experimental farm of the Poltava State Agrarian Academy, which by territorial distribution belongs to the central part of the Forest-Steppe of Ukraine. The arable soil layer has the following agrochemical characteristics (Table 1).

The weather conditions were contrasting during the investigation. Deviations from a norm (average long-term indicators) of both air temperature and precipitation were fixed. These indicators were uneven at the stages of winter wheat organogenesis, especially during the period of formation and filling of winter wheat grain (Figs 1–2).

Table 1. Characteristics of the soil conditions of the experimental field

Soil type	Typical podzolic black soil
Humus content	3.07–3.23%
Moving phosphorus content	10 mg per 100 gram of soil
Exchangeable potassium content	13 mg per 100 gram of soil
Degree of soil saturation with substrates	84–87%
pH (salt)	6.8–7.1
Hydrolytic acidity	4.37–9.9 mg eqv^{-1}

Agricultural techniques of winter wheat cultivation combined step-by-step implementation of agrarian measures: basic (disking, plowing, 3 autumn cultivations), fertilizing with 30 kg ha^{-1} N, 60 kg ha^{-1} P, 60 kg ha^{-1} K (autumn plowing) and sowing taking into account the sowing qualities of seed (at the rate of 4.5 million seeds per 1 ha and taking into account the experiment factors), fertilizing with KAC (urea-ammonia mixture) in period of restoration of spring vegetation, harvesting (full grain ripening).

The experiment is multifactorial and combines two stages. The variants in the experiment were laid out by a randomized method in a fourfold repetition. The accounting area of the plot is 50 m^2.

The scheme of multifactorial experiment included the following factors (Fig. 3):

– factor A – the conditions in which winter wheat seed was formed at the stage 71–77 according to BBCH codes: A.1 – optimal (HTC is about 1.0), A.2 – arid (HTC < 1.0), A.3 –wet (HTC > 1.0);

– factor B – winter wheat varieties: B.1 – 'Chyhyrynka' (Ukrainian plant breeding) and B.2 – 'Kubus' (foreign plant breeding);

– factor C – size of seed material: C.1 – initial seed sample (control), (TKW 40.8 ± 0.5 g), C.2 – large seed (TKW 50.4 ± 0.5 g), C.3 – average seed (TKW 41.5 ± 0.3 g), C.4 – fine seed (TKW 30.6 ± 0.7 g).

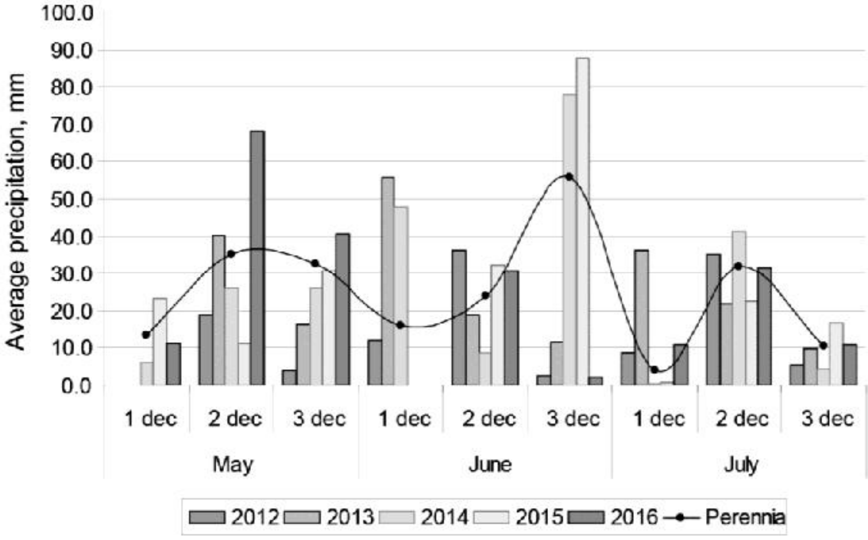


Figure 1. Weather conditions (precipitation) during spring-summer vegetation of winter wheat, 2012–2016.
Note: dec- ten day period; Perennial – average value of long-term data.

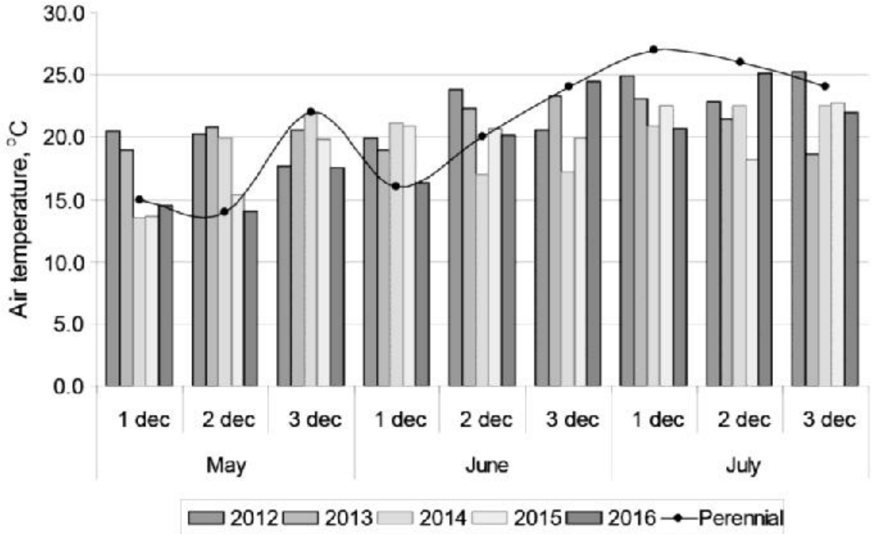


Figure 2. Weather conditions (air temperature) during spring-summer vegetation of winter wheat, 2012–2016.
Note: dec- ten day period; Perennial – average value of long-term data.

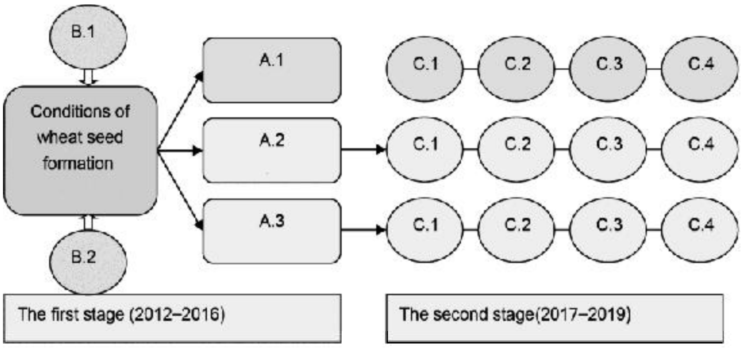


Figure 3. Stages of researches.
Note: B.1 – variety 'Chyhyrynka', B.2 – variety 'Kubus'; A.1, A.2, A.3 – conditions of seed cultivation; C.1 – initial seed sample (control), C.2 – large seed, C.3 – average seed, C.4 – fine seed.

Analyses and accountings during vegetation period were performed according to the generally-accepted methods (Tekrony, 2006; Tkachyk, 2014).

Hydrothermal coefficient (HTC) was determined by the formula that reflects both temperature factor and precipitation during the certain period (period of grain formation and filling). Hydrothermal coefficient (HTC), precipitation and the air temperature **(**above +10) were calculated by the following relation:

$$HTC = \Sigma R \times 10 / \Sigma t,$$

where R – is the sum of precipitation (mm) during the period; t – the sum of average daily temperatures °C during the same period; 10 – coefficient.

The given condition, if HTC < 0.4 – very strong drought, HTC from 0.4 to 0.5 – strong drought, HTC from 0.6 to 0.7 – medium drought, HTC from 0.8 to 0.9 – weak drought, HTC from 1.0 to 1.5 – sufficiently wet conditions, HTC > 1.5 – excessively wet conditions.

Yield was calculated on each plot of land, weighing grain from each variant by repetitions. Protein content in wheat grain was determined according to Kjeldahl method (by Kjeldahl digestion) (Kjeldahl, 1983).

The research results were calculated by the dispersion analysis (ANOVA and MANOVA) in order to define the significant differences between the variants. Fisher's LSD test ($p < 0.05$) was applied to determine the effect of weather conditions and significance assessment on the grain quality. Correlation-regression analysis using correlation coefficients (r) and trait determination (d) at significance levels ($p < 0.05$) was also applied.

RESULTS AND DISCUSSION

Effect of HTC and variety on protein content

The data on air temperature and precipitation was used in order to characterize the weather conditions of the period of grain formation and filling. HTC has been calculated for each year as well.

It has been determined that the weather conditions during the research years – in the period from jelly-like state to full grain ripening differed from each other (Table 2).

Table 2. Characteristics of the climatic factors in the period from jelly-like state to full ripening of winter wheat grain

Research year	Period duration, days	Sum of active air temperatures, °C		Sum of precipitation, mm		HTC
		average	deviance from a norm	average	deviance from a norm	
2012	24.0	68.4	-8.7	8.6	+ 14.6	1.3
2013	28.0	67.8	-9.3	36.4	+ 32.4	5.4
2014	22.0	60.6	-16.5	1.3	- 3.7	0.2
2015	23.0	60.5	-16.4	0.8	- 3.2	0.1
2016	25.0	70.3	-6.8	10.9	+ 6.9	1.6
Norm (average annual value)	-	77.0	-	4.0	-	-

It has been determined that the duration of the period of winter wheat seed formation and filling is longer, if HTC is lower, and vice versa.

The period of seed formation and filling in 2012 was at the average daily air temperature of 22.8 °C, which is 2.9 °C below the average annual temperature. The effective temperature sum was 68.4 °C. The period was characterized by precipitation at the level of 18.6 mm, while the average annual precipitation was 4.0 mm. The hydrothermal coefficient was 1.3, indicating the sufficiently wet conditions of this period. Excessively wet conditions were formed during the winter wheat seed formation in 2013: the temperature factor was below the norm by 3.1 °C, and the precipitation was excessive – more than the norm by 32.4 mm, the HTC was at a level of 5.4. During 2014 and 2015, the average daily air temperature raised from 17.0–20.7 (jelly-like state of grain) to 22.5–22.7 °C (waxy grain ripening) while precipitation decreased by 3.2–3.7 mm compared to the norm.

The average daily air temperature in 2016 during the period of grain filling and formation was almost at the level of norm, and precipitation is higher by 6.9 than HTC – at the level of 1.6.

Therefore, the results of observations described the periods of wheat grain formation and filling in the conditions of 2012 and 2016 as the sufficiently wet conditions, 2014 and 2015 as very arid, and 2013 as excessively moist.

Weather conditions significantly affected the protein content in winter wheat grain of the studied varieties (Table 3). That is why, the conditions of the period of grain formation and filling have been distinguished as follows: close to the optimal (2012 and 2016), arid (2014 and 2015), and wet (2013). This made it possible to fairly analyze their effect on the accumulation of protein content in winter wheat grain, grain and protein yield, which subsequently served as a seed material for the second stage of research.

High precipitation during the period of seed formation and ripening and low average daily air temperature in 2013 reduced the protein content in winter wheat grain of the studied varieties. The protein content was lower in grain, which was formed in the conditions close to optimal (2012 and 2016). The best quality of grain was provided by winter wheat varieties in 2014 and 2015 in arid and stressful conditions during the period of grain formation and filling.

Table 3. Winter wheat yield and Protein content in grain of 'Chyhyrynka' and 'Kubus' varieties, 2012–2016

Conditions of seed formation (Factor A)	Varieties (Factor B)	Protein content in grain, %	Grain yield, kg ha^{-1}	Protein yield, kg ha^{-1}
Optimal	Chyhyrynka	13.0* [a]	4,400.0* [a]	572.0* [a]
	Kubus	13.4* [b]	4,800.0* [b]	643.2* [b]
Dry	Chyhyrynka	13.9* [a]	3,900.0* [a]	542.1* [a]
	Kubus	14.0* [b]	4,100.0* [b]	569.9* [b]
Wet	Chyhyrynka	12.7* [a]	4,500.0* [a]	571.5* [a]
	Kubus	13.2* [b]	4,900.0* [b]	646.8* [b]

MANOVA: Factor A *; Factor B [ab]. Different letters indicate significant differences. Significant effects: $p < 0.05$ (*). Same letters indicate that no significant differences were found.

On the basis of correlation-regression analysis, a similar effect of weather conditions on the HTC index of the period of grain formation and filling on the protein content in winter wheat grain, irrespective of the origin of the varieties, has been determined (Fig. 4).

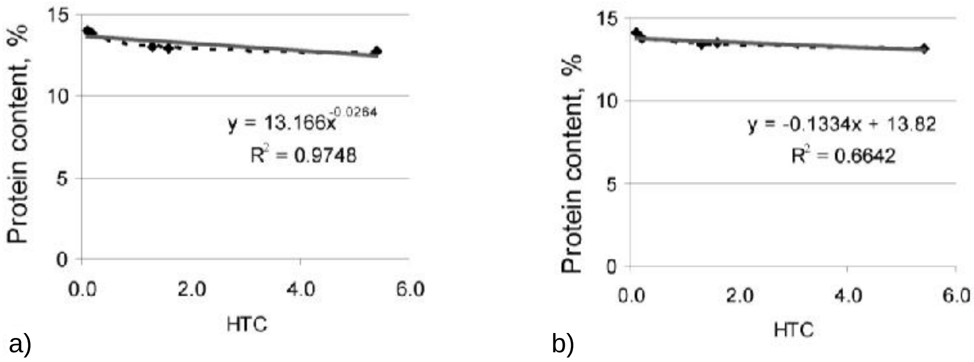


Figure 4. Dependence (according to the coefficient of approximation of traits) between protein content in grain of winter wheat variety 'Chyhyrynka' (a) and variety 'Kubus' (b) and HTC of the period of seed formation and ripening, 2012–2016.

The strong correlation was observed ($R^2 = 0.97$) during the interaction of HTC (period of grain formation and filling) and protein content in winter wheat grain of variety 'Chyhyrynka'. The variety 'Kubus' shows a similar dependence: in dry years of the period of grain formation and filling at HTC, the protein content increases in the dry season, these indicators have a correlation of mean force was observed $R^2 = 0.66$.

Our researches are consistent with the data obtained by the authors (Linana & Ruza, 2015). They found the following peculiarity: if during the period of grain ripening, warm weather with the lowest precipitation is observed, wheat accumulates more protein. The amount and quality of gluten was mostly affected by the weather conditions of the research year, but the variety also slightly affected the variability of the grain protein content (Linina & Ruza, 2015).

Other studies of these authors (Linina & Ruza, 2018) determined the impact of nitrogen application and growing technology on the yield and found a medium strong positive correlation between HTC in the period from the formation to the ripening of winter wheat grain.

Petrenko et al., 2017 found out that wheat grain, grown by the intensive farming system, had better quality than other variants of the experiment. In some experimental years, weather conditions played an important role in the formation of baking properties, as well as the efficiency of plant nutrition and protection was noted.

In the following experiment, the authors (Mäkinena et al., 2018) evaluated the sensitivity of European wheat yields to the extreme weather phenomena connected with the sowing phenology while testing varieties across Europe (latitude from 37.21 °C to 61.34 °C and longitude from 6.02 °C to 26.24 °C) in the period of 1991–2014. All observed agro-climatic extremes (≥ 31 ° C, ≥ 35 °C, or drought from ear formation to seed ripeness; excessive precipitation; heavy precipitation and low global radiation) resulted in significant yield losses of the studied European varieties. There were no European wheat varieties that responded positively to drought after sowing at + 10 °C or to low temperatures in winter (in the range of −15 °C and −20 °C). These data correspond to our investigations, carried out in the conditions of the central Forest-Steppe of Ukraine.

Effect of seed formation and fraction of seed material on protein content and yield
The second stage of the research involved the study of influence of the conditions of seed formation and its size on the protein content in grain of the new winter wheat yield (Table 4, 5).

Table 4. Winter wheat yield and Protein content in grain of variety 'Chyhyrynka' in relation to the period of seed formation and ripening and its size, 2017–2019

Conditions of seed formation (Factor A)	Seed fraction (Factor C)	Protein content in grain, %	Grain yield, kg ha^{-1}	Protein yield, kg ha^{-1}
Optimal	control	13.7	3,800.0	520.6
	large	13.4	4,200.0	562.8
	average	13.8	4,400.0	607.2
	fine	14.1	4,900.0	690.9
Dry	control	13.6	3,900.0	530.4
	large	13.8	4,400.0	607.2
	average	14.2	4,500.0	639.0
	fine	14.5	5,000.0	725.0
Wet	control	13.2	5,400.0	712.8
	large	13.0	5,700.0	741.0
	average	13.3	6,200.0	824.6
	fine	13.7	5,900.0	808.3
$LSD_{0.95}$(Factor A)		0.06	11.3	12.9
$LSD_{0.95}$(Factor C)		0.04	75.4	6.5
$LSD_{0.95}$(Factor A and C)		0.08	8.1	7.8

*Note – The obtained differences between the variants of winter wheat variety 'Chyhyrynka' are confirmed by the mathematical analysis MANOVA.

Table 5. Winter wheat yield and protein content in grain of variety 'Kubus' in relation to the period of seed formation and ripening and its size, 2017–2019

Conditions of seed formation (Factor A)	Seed fraction (Factor C)	Protein content in grain, %	Grain yield, kg ha^{-1}	Protein yield, kg ha^{-1}
Optimal	control	13.8	4,700.0	648.6
	large	13.6	5,000.0	680.0
	average	14.1	5,200.0	733.2
	fine	14.3	5,900.0	843.7
Dry	control	13.9	4,800.0	667.2
	large	14.2	5,300.0	752.6
	average	14.6	6,100.0	890.6
	fine	14.8	6,400.0	947.2
Wet	control	13.3	5,100.0	678.3
	large	13.5	5,300.0	715.5
	average	13.8	5,900.0	814.2
	fine	13.6	5,600.0	761.6
$LSD_{0.95}$(Factor A)		0.04	108.2	13.4
$LSD_{0.95}$(Factor C)		0.02	71.3	7.5
$LSD_{0.95}$(Factor A and C)		0.05	80.4	8.9

**Note* – The obtained differences between the variants of winter wheat variety 'Chyhyrynka' are confirmed by the mathematical analysis MANOVA.

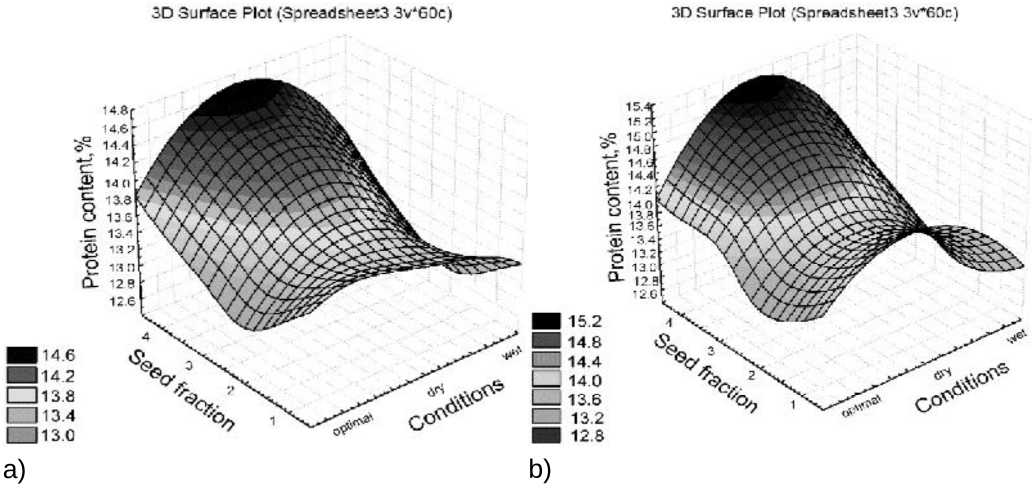
It has been found that the protein content in winter wheat grain of variety 'Chyhyrynka' varied in the range of 13.0 to 14.5%, grain yield varied from 3,800 to 6,200 kg ha^{-1}, protein yield varied from 520.6 to 824.6 kg ha^{-1} depending on the studied factors. The lowest protein content in winter wheat grain was formed during sowing with large seed: in the range of 13.0 to 13.8%, protein yield –520.6; 530.4 and 712.8 kg ha^{-1}. Index of protein yield depending on grain yield also.

Variety 'Chyhyrynk' a provided the highest protein content in winter wheat of the new yield by sowing fine seed, obtained in the optimal conditions (14.1%) and arid conditions (14.5%). The shallow fraction of seed, obtained in the wet years, although increases the protein content in winter wheat grain, but this index was greatly lower (< 14.0%) compared to grain, formed during the optimal and dry years. In research years increase in protein yield was formed during sowing with small seeds fraction, except wet conditions where increase in protein yield was formed during sowing with average seeds fraction.

Protein content in winter wheat grain of variety 'Kubus' varied in the range of 13.1 to 14.8% depending on the studied factors. The lowest protein content in grain was formed during sowing with large seed: in the range of 13.5 to 13.9%. Protein yield from 843.7–947.2 kg ha^{-1} was formed during sowing with small seeds fraction, except wet conditions of seeds forming where protein yield (814.2 kg ha^{-1}) was formed during sowing with average seeds fraction (Table 5).

Winter wheat variety 'Kubus' provided the highest protein content in grain due to sowing with fine seed that was formed under the optimal conditions (14.3%) and the arid conditions (14.8%). Compared to the control and other variants, the shallow fraction of seed, obtained in wet years, did not increase the protein content in winter wheat grain and protein yield.

Graphs 3-D show and confirm the connection between the conditions of the period of seed formation and filling, its size and protein content (Fig. 5).



Note: C.1 is the initial sample of winter wheat seed (control), C.2 is the large winter wheat seed, C.3 is the average winter wheat seed, C.4 is the fine winter wheat seed.

Figure 5. Connection between the seed growing conditions, its size and protein content in grain of wheat varieties: a – variety 'Chyhyrynka', b – variety 'Kubus', 2017–2019.

While establishing a correlation between protein content and seed size, it has been determined that these indicators are interdependent at r = 0.59 for winter wheat variety 'Chyhyrynka' and r = 0.53 for variety 'Kubus'.

Our researches correspond with the findings of scientists (Savill et al., 2018) who have developed a new method of analysis for the quantitative assessment of both protein concentration gradients and protein body size distribution in wheat plants endosperm. The plants were grown at two different temperatures (20.0 °C or 28.0 °C) during the period of seed formation and filling. It has been determined that the protein content of wheat grain also varies depending on the fertilizing options: high or low nitrogen content. The authors of the publication found out that increased temperatures of the period of generative development of wheat at the background of high nitrogen supply increases the protein content of grain. This feature can also be used in the plant breeding process (Pereira & Coimbra, 2019).

The results of field experiments by other scientists (Popko at al., 2018) showed that the application of amino acid-based products had an effect on growth of the grain yield of winter wheat (5.4% and 11%, respectively, when using AminoPrim at a dose of 1.0 L ha^{-1} and AminoHort at a dose 1.25 L ha^{-1}) in comparison with the control group (without biostimulant). Laboratory trials have shown the improvement of such technological characteristics of winter wheat grain, as ash content, Zeleny sedimentation index and protein content. This is in line with the perspectives of our further investigations, which will aim at the determination of the effect of weather conditions and foliar nutrition with chelate preparations in the different phases of winter wheat growth and development on its yield and grain quality. The study of the complex effect of weather conditions and agrarian measures of cultivation in connection with the size of winter wheat seed and protein content is also envisaged.

CONCLUSIONS

1. The nature of the physiological mechanism and the biochemical essence of the protein content in winter wheat grain under the influence of weather factors have been discovered on the basis of intellectual search and experimental studies. Dependencies have been established: stressful conditions of wheat cultivation at high air temperature and low-effective precipitation during the period of grain formation and filling increase the protein content in it, and vice versa.

2. The tendency of impact of temperature and precipitation of the period of seed formation and filling in winter wheat maternal plants on quality of the obtained grain has been determined. It has been found out that the highest protein content in grain of the studied winter wheat varieties was observed at the low hydrothermal coefficient (< 0.5). The correlation between protein content in grain and HTC of the period of seed formation and ripening of winter wheat variety $R^2 = 0.97$ for variety 'Chyhyrynka' and $R^2 = 0.66$ for variety 'Kubus'.

3. The variability of protein content in winter wheat grain was determined depending on the formation conditions and in relation to the size of seed fraction of the offspring. When sowing larger seed, the protein content in obtained grain of variety 'Chyhyrynka' will be lower by 0.6–0.7% and protein content of variety 'Kubus' will be lower by 0.6–0.8%, compared to the sowing of fine seed. The correlation between grain protein content and seed size has been confirmed at $r = 0.59$ for variety 'Chyhyrynka' and $r = 0.53$ for variety 'Kubus'. It is established that sowing with medium and small seeds fraction obtained in optimal and dry conditions allows to increase grain yield, protein content and yield at the same time. Small seeds obtained in humid conditions do not increase grain and protein yield. This regularity is established for both varieties.

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