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THE IMPACT OF NUTRITION OPTIMIZATION ON CROP YIELD OF WINTER WHEAT VARIETIES (*TRITICUM AESTIVUM* L.) AND MODELING OF REGULARITIES OF ITS DEPENDENCE ON STRUCTURE INDICATORS

SUMMARY

The article presents the results of studies conducted in 2011 -2016 years on the southern chernozem in the southern Steppe of Ukraine, studied the efficiency of processing winter wheat crops modern growth-regulating drugs in the main periods of vegetation of the crop on the background of mineral fertilizers application. It was determined that the introduction of pre-sowing cultivation of winter wheat fertilizer in a dose of $N_{30}P_{30}$ (background) and the use of foliar fertilizing of crops at the beginning of the resumption of spring vegetation and the beginning of stooling complex organic fertilizers Organic D2 and Escort-bio created favorable conditions for the formation of optimal indicators of the structure of the crop and, accordingly, a high level of grain yield of the studied varieties. In the variants of fertilizer Organic D2 and Escort-bio plants of winter wheat variety Kolchuga formed 4,42-4,48 t / ha of grain, and plants of Zamozhnist formed 4,96 – 4,99 t/ha, which exceeded the control by 52,9 – 55,0 and 62,6-63,6%, respectively. From the studied varieties of winter wheat on a set of indicators, it was determined Zamozhnist as the best variety.

Key words: winter wheat, variety, plant nutrition, crop structure, grain yield, modeling of regularities.

INTRODUCTION

Today, grain production has a special place in the structure of the agro-industrial complex. It is the grain and products of its processing which are vital products that ensure the food security of the state, play an important role in the socio-economic development of the national economy, form the basis of agricultural exports and determine the degree of its participation in international cooperation. Favorable natural and climatic conditions and fertile lands of Ukraine allow to grow all crops and to receive high-quality food products in sufficient volumes both for domestic needs and for the formation of export potential (Kushniruk and Tolmach, 2016). Over the past five years, Ukraine strengthened its position in the international agricultural market and it is confidently in the world's top ten grain producers. Wheat is the top food crop in

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Ukraine as well as in the whole world and the biggest part of grain is obtained primarily from winter wheat. The total area for winter wheat cultivation in Ukraine covers 6.8 mln. ha with actual productivity of 24 mln. tons and average capacity of 2.8 t/ha. Due to its favorable natural and climatic conditions the South of Ukraine is considered one of the leading regions for the production of soft winter wheat of high quality (Korchova et al., 2018; Nazarenko and Kharytonov, 2016).

Improving the technology of winter wheat growing is an extremely urgent task, because in the current economic conditions, reducing the cost of grain production and increasing its profitability it is possible only in the case of the introduction of new agricultural techniques which do not involve large costs. Modern intensification of crop production in the conditions of acute shortage of organic fertilizers and too high prices for mineral fertilizers provides for the development of alternative measures for the technology of growing crops. In this context, it is becoming increasingly important to study the effect of high-performance polymer chelated fertilizers, biological products, growth-regulating drugs, etc. in combination with other agrotechnical elements on the formation of biometric indicators of plants, yield and product quality (Rozhkov and Gutyansky, 2017). There is a need to develop and implement resource-saving elements of plant nutrition technology, which consist in the introduction of low doses of mineral fertilizers and on their background the use of foliar fertilizing with modern drugs in the main periods of their vegetation (Panfilova and Gamayunova, 2018).

Research of grain yield is the main objective of modern agricultural science (Macholdt and Honermeier, 2017). It primarily depends on such structural elements as the number of productive stems per unit area, the number of grains in the ear and its mass, the 1000 grains weight, etc. Larger grain has better indicators of quality and germination, which contributes to the formation of higher crop yields (Campbell et al., 1999; Dholakia et al., 2008; Breseghello and Sorrells, 2006; Sun et al., 2008; Chamurliyski et al., 2015). It should be noted that the indicators of the yield structure depend on the varietal characteristics of culture and agrotechnology of its cultivation (Cooper et al. 2001), therefore, the purpose of our research was to study the effect of optimizing the nutrition of winter wheat plants on crop productivity and modeling the laws of dependence of its yield on the structure indicators.

MATERIALS AND METHODS

Experimental studies were conducted during 2011-2016 years on the experimental field of the Mykolaiv National Agrarian University (Mykolayiv district, Mykolaiv region, Ukraine). The object of research was winter wheat varieties such as Kolchuga and Zamozhnist. The variety Kolchuga (variety-lutescen) refers to the early maturing varieties, its vegetation period is 275-278 days. The height of the plant is medium-sized (96 cm). In the field conditions during the testing years winter hardiness is 8.8 points, resistance to lodging is 8.7

points, resistance to shedding is 8.9 points, drought resistance is 8.1 points. It is the variety of intensive type, universal use. The variety Zamozhnist (variety – erythrospermum) is mid-ripening. The vegetation period is 282-287 days. Plant height is 94-104 cm, the variety is highly resistant to lodging and shedding, frost and winter hardiness above average, it is characterized by high drought and heat resistance. It is the variety of high-intensity type and universal use on different agricultural backgrounds.

The technology of growing winter wheat in the experiment, with the exception of the studied factors, was generally accepted to the existing zonal recommendations for the southern steppe of Ukraine. The territory of the farm is located in the third agro-climatic region and it belongs to the subzone of the southern Steppe of Ukraine. The climate is temperate continental, warm, dry, with unstable snow cover. Weather conditions for hydrothermal indicators in the years of research varied, which made possible to obtain objective results, but in general, they were typical for the location of the farm.

The soil of experimental sites was represented by the southern, resiliently weakly sunny, heavy-sooty black soilon the loesses. The reaction of the soil solution was neutral (pH 6.8 - 7.2). The content of humus in the 0 - 30 cm layer was 123 - 125 g kg^{-1}. The arable layer of soil contained moving forms of nutrients on average: nitrates (by Grandval Liagou - this method is based on interactions between nitrates and disulpfo-phenolic acid from which trinitrophenol (picric acid) is formed. In alkaline environment it gives us yellow coloring due to formation of potassium trinitrophenolate (or natrium, depending from alkali used) in quantity equivalent to nitrates content) as 15 - 25 mg kg^{-1}, mobile phosphorus (by Machigin - this method is based on extraction of mobile phosphorus and potassium compounds from the soils with 1% ammonium carbonate solution, pH 9.0, at 25 ± 2^{0}C) as 41 – 46 mg kg^{-1}, exchangeable potassium (on a flame photometer) as 389 - 425 mg kg^{-1}of soil.

The experiment scheme included the following variants:

Factor A – variety: 1. Kolchuga; 2. Zamozhnist.

Factor B – nutrition: 1. Control (without fertilizers); 2. $N_{30}P_{30}$-for pre-sowing cultivation-background; 3. Background + urea K1 (1 l/ha); 4. Background + Urea K2 (1 l/ha); 5. Background + Escort-bio (0,5 l/ha); 6. Background + urea K1 + Urea K2 (0.5 l/ha); 7. Background + Organic D2 (1 l/ha).

The norm of the working solution was 200 l/ha. Fertilizing of crops with modern growth regulating drugs was carried out at the beginning of the resumption of spring vegetation and at the beginning of the winter wheat stooling. Plants of the control variant were sprayed with tap water in the specified phases of growth and development.

Preparations used for foliar nutrition of winter wheat crops are included in the list of pesticides and agrochemicals allowed for use in Ukraine. Preparations Urea K1 and Urea K2 are registered as fertilizers which contain respectively N as 11-13%, P_2O_5 as 0,1-0,3%, K_2O as 0,05-0,15%, trace elements as 0,1%, succinic acid as 0,1% and N as 9 -11%, P_2O_5 as 0,5 – 0,7%, K_2O as 0,05 – 0,15%,

sodium humate as 3 g/l, potassium humate as 1 g/l, trace elements as 1 g/l. Organic D2 is a organo-mineral fertilizer, which contains N as $2,0 – 3,0\%$, P_2O_5 as $1,7 – 2,8\%$, K_2O as $1,3 – 2,0\%$, calcium total as $2,0 – 6,0\%$, organic substances as $65 – 70\%$ (in recalculation on carbon). Escort-bio is a natural microbial complex which contains strains of microorganisms of the genera Azotobacter, Pseudomonas, Rhizobium, Lactobacillus, Bacillus and biologically active substances (BAS) produced by them.

In the process of research the method it was used the state variety testing of agricultural crops (Volkodav et al., 2001). The structure of the crop was analyzed by sheaves, which were selected before harvesting from sites of 1 m^2. The yield structure was determined by the method of continuous harvesting of each accounting area (grain harvester "Sampo-130").

Statistical dependence of winter wheat yield was studied on the basis of correlation and regression analysis, the task of which was to establish the form of dependence between the indicators, evaluation of the regression function and prediction of the values of the dependent variable. In general, the yield of winter wheat is characterized by a nonlinear dependence. Since, in this form of connection, the increasing in the factor characteristic leads to an uneven increasing (or decreasing) in the effective characteristic, or the growth of its value varies in descending order, and the decrease in increasing, then at a certain small interval the yield is estimated by the equation of linear multivariate regression of the form:

$$\hat{y}_x = a_0 + a_1 x_1 + a_2 x_2 + K + a_n x_n, (1)$$

where $\hat{y}_x$ - dependent variable, $x_1, x_2, ..., x_m$ - independent factors,

a_0, a_1, a_2, ..., a_n - parameters of the model.

RESULTS AND DISCUSSION

The crop yield structure is a quantitative expression of the result of the life of the plant organism, which determines the value of the crop and reflects the interaction of plants and the environment at certain stages of growth and development. Important components of the crop yield structure of the winter wheat are the length of the ear, the number of grains in the ear, the weight of the grain per ear and the 1000 grains weight (Table 1).

On average, over the years of research and on nutrition factor, the winter wheat variety Zamozhnist had a slightly longer ear length by 6.5%. It should be noted that the longest ear was characterized by plants of both studied varieties of winter wheat on the nutrition variants Background + Organic D2 and Background + Escort-bio. So, on average, over the years of research, the length of the ear of plants of winter wheat variety Kolchuga on these variants of the experiment was 9.0-9.2 cm, the length of the ear of variety Zamozhnist was 9.8-10.1 cm, which exceeded the control version, respectively, by 15.4-17.9 and 19.5-23.2%.

On average, over the years of research, nutritional variants to some extent influenced on the number of grains in the ear of the studied varieties of winter wheat. Thus, if no application of fertilizers the ear of plants variety Kolchuga consisted of 24.9 PCs, and the ear of plants variety Zamozhnist consisted 27,5 PCs, use of seed and application of only mineral fertilizers ensured the increasing of this indicator in the context of the undertaken study on the varieties 6.8 – 7.8 % and for the background of fertilizers foliar nutrition it increased by 11.1 – 16.4% for the cultivation of variety Kolchuga and it increased by 8.9 - 13.2% for variety Zamozhnist.

Table 1. The structure of the yield of winter wheat varieties depending on the diet (average for 2012-2016 years)

Variety	Nutrition variant	Structure indicators			
		Length of ear, cm	The number of grains in the ear, PCs	The weight of grain per the ear, g	The 1000 grains weight, g
Kolchuga	Control	7,8	24,9	0,88	35,0
	$N_{30}P_{30}$ (background)	8,4	27,0	1,00	36,8
	Background +Urea K1	8,5	28,0	1,08	38,3
	Background + Urea K2	8,6	28,2	1,11	39,2
	Background + Urea K1 + Urea K2	8,9	28,7	1,15	31,1
	Background + Escort-bio	9,2	29,8	1,25	41,9
	Background + Organic D2	9,0	29,3	1,19	40,5
Zamozhnist	Control	8,2	27,5	1,02	36,9
	$N_{30}P_{30}$ (background)	8,7	29,5	1,15	38,9
	Background +Urea K1	9,2	30,2	1,23	40,7
	Background + Urea K2	9,1	30,5	1,26	41,3
	Background + Urea K1 + Urea K2	9,6	31,2	1,31	42,1
	Background + Escort-bio	10,1	31,7	1,35	42,7
	Background + Organic D2	9,8	31,3	1,32	42,1

A slightly larger number of grains in the ear during all the years of research was formed by plants of variety Zamozhnist. So, on average for years of researches on the nutrition factor, they were formed 30.3 PCs, which exceeded the variety Kolchuga by 2.3 PCs or by 7.6%.

We found that, on average, over the years of research, varieties and nutrition variants were reflected in the weight of grain per ear. So, for the introduction of the background recommended dose of mineral fertilizer for winter wheat variety Kolchuga the weight of grain from the ear compared to the inconvenient control increased by 12.0%, and it increased for the variety of Zamozhnist by 11.3%. Carrying out foliar fertilizing on the background of mineral fertilizers increased this indicator of the crop structure by 18.5 – 29.6 and 17.1 – 24.4%, respectively, to the control.

It was noted that the 1000 grains weight of winter wheat depended primarily on the varietal characteristics of the crop. So, on average, over the years of research on the nutrition factor, the 1000 grains weight of the Kolchuga variety was 37.5 g, which was less than the indicators for the variety of Zamozhnist by 3.2 g or 7.9%.

It should be noted that the introduction of mineral fertilizers in a moderate dose for pre–sowing cultivation contributed to the growth of this indicator, depending on the variety, by 4.9-5.1%. Carrying out foliar fertilizing of plants during the growing season with modern growth- regulating drugs contributed to increasing in the 1000 grains weight of the Kolchuga variety by 3.3 – 6.9 g or by 8.6 – 16.5%, and it increased for variety Zamozhnist by 3.8 – 5.8 g or 9.3-13.6% respectively. Thus, irrespective of the studied varieties of winter wheat the highest 1000 grains weight was observed on applicating of the drug Escort-bio background $N_{30}P_{30}$ as 41.9 – 42.7 g.

In the effective use of fertilizers, an important role belongs to the variety (Fig. 1).

Thus, on average, over the years of research and nutrition factor, the grain yield of winter wheat variety Zamozhnist compared with the yield of variety of Kolchuga formed higher by 0.41 t/ha or 10.2%.

In our studies, the increasing in grain yield of winter wheat variety Zamozhnist for the introduction of $N_{30}P_{30}$ in the control was 0.53 t/ha or 17.4%. The use of growth-regulating drugs on the background of application of $N_{30}P_{30}$ provided the increasing in grain yield of winter wheat 1,59-1,94 t/ha or 52,1 – 63,6% depending on the drug.

Foliar nutrition of winter wheat variety Kolchuga also had a positive impact on grain yield. So, on average for years of researches specified agronomic techniques contributed to the increasing in the yield by from 1,34 up to 1.59 t/ha or by 46.4 – 55.0 % in comparison to the control.

The use of plant growth-regulating drugs on winter wheat and other crops is a common practice (Panfilova and Gamayunova, 2018; Yeremenko et al., 2018). Thus, in the UK, the use of plant growth-regulating drugs in the spring vegetation period contributed to the growth of grain yield by 4 t / ha, compared

with the natural background (Griffin and Hollis, 2017). Nutrition is an important factor in the cultivation of wheat, as it affects the growth, yield and quality of grain. Studies by Yuxue Zhang et al. conducted in the greenhouse at the Ottawa Research and Development Centre (ORDC) showed that growth-regulating drugs contributed to an increase in plant height, but the grain yield decreased.
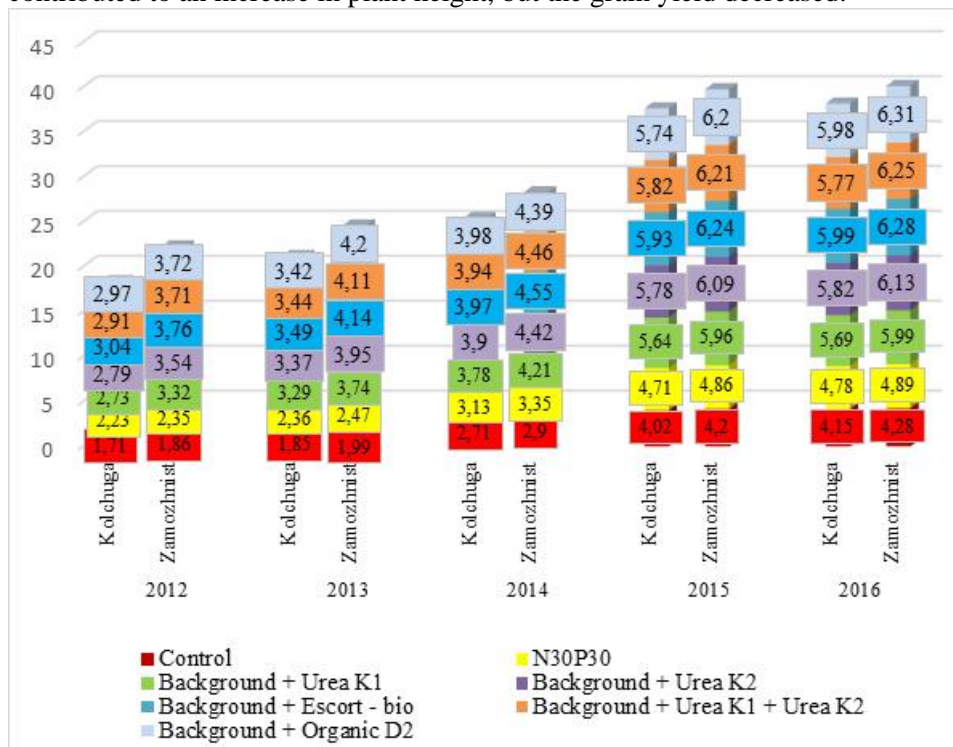

Figure 1. The crop yield of winter wheat on the different nutrition variants, t/ha

Higher crop yields are likely to be contributed by resource-saving technologies which increase the yield of crops up to 10-15% (Markov et al., 2011; Dwyer et al., 1995). The combined use of organic and mineral fertilizers in combination with humic substances in studies by Indian scientists increased the yield of wheat by 27% and it had a positive effect on the nutrient content and organic carbon in the soil (Bharali et al., 2017).

Yield of many crops rarely meets its maximum potential for production (Smith et al., 2018). In our research the yield of winter wheat greatly depended on the variety features. Currently, the variety acts as an independent factor in increasing of grain yield (Panfilova and Gamayunova, 2018; Nazarenko et al., 2019). According to Ayranci et. al., (2014) and Ahmadi et. al. (2016), on the contrary, the grain yield was more dependent on environmental conditions during the growing season than on the genotype effect.

We would determine the statistical dependence of winter wheat yield in our studies on the structural elements on the basis of correlation and regression analysis, as it could give an idea of the change in the effective feature in the variation of factor variables. Also, the results of regression analysis of the data of long-term multifactor field experiments make it possible to derive mathematical models of the relationship of crop yields with the factors that determine them.

The yield of winter wheat depends on the level of manifestation of the structure elements, such as the length of the ear, the number of grains in the ear, the mass of grain from the ear and so on, which vary significantly under the influence of agrotechnical factors, in particular due to the nutrition method.

For identifying the dependence of the yield on the structure indicators we construct a correlation matrix, such as a matrix of paired correlation coefficients. Let's determine the variables of the econometric model: let Y – winter wheat yield, t/ha; X_1 – the ear length, cm; X_2 – the number of grains in the ear, PCs.; X_3 – the mass of grain from the ear, g; X_4 – the 1000 grains weight, g (Table 2).

Table 2. The paired correlation coefficients of relationship of yield and structure indicators (average for 2012 – 2016 years)

Nutrition variant	Variety			
	X_1	X_2	X_3	X_4
Variety Kolchuga				
Control	0,775867	0,949413	0,964352	0,953291
$N_{30}P_{30}$ (background)	0,934191	0,520464	0,98125	0,949085
Background + Escort-bio	0,860109	0,804483	0,979362	0,927868
Variety Zamozhnist				
Control	0,824169	0,904006	0,989757	0,988779
$N_{30}P_{30}$ (background)	0,87356	0,965198	0,977377	0,975628
Background + Escort-bio	0,95136	0,939118	0,980013	0,983574

To determine the closeness of the connection of independent indicators on the factor characteristic, we find the pair correlation coefficients, as the higher the coefficient value is, as the greater the influence of the factor is on the yield. According to the results of our calculations, in the control version of the experiment the number of grains in the ear, the mass of grain from the ear and the 1000 grains weight had the greatest impact on the yield of winter wheat variety Kolchuga. When applying mineral fertilizers for pre-sowing cultivation in a moderate dose of $N_{30}P_{30}$ and the background + Escort-bio nutrition variant, a strong relationship was observed between the yield and the length of the ear, the weight of the grain from the ear and the 1000 grains weight.

Analyzing the calculations on the variety of wheat Zamozhnist, it could be concluded that on the control option and the option of making $N_{30}P_{30}$ the number of grains in their ear, the mass of grain from the ear and the 1000 grains weight

had the greatest impact on yield. Foliar nutrition of winter wheat crops in the main periods of vegetation with the drug Escort – bio on the background of application of $N_{30}P_{30}$ contributed to the creation of a strong relationship between the yield and the length of the ear, the weight of the grain from the ear and the 1000 grains weight.

Let's construct a linear multivariate regression of the form (1), taking into account those exogenous variables which have the strongest relationship with the endogenous variable (Table 3).

Let's provide the correlation analysis of regression equation for winter wheat variety Kolchuga on application of moderate doses of mineral fertilizers ($N_{30}P_{30}$):

$$Y = 0,007 + 0,083X_1 + 16,99X_3 - 0,39X_4$$

From the regression equation, we could see that for increasing in the length of the ear X_1 (cm) by 1%, the yield of winter wheat would increase by 0.083 t/ha, and for increasing in X_3 (the weight of grain from the ear, g) it would increase by 16.99 t/ha. It should be noted for increasing in X_4 (the 1000 grains weight, g) by 1%, the yield of winter wheat would decrease by 0.39 t/ha.

Table 3. Mathematical modeling of winter wheat crop structure (average for 2012 – 2016 years)

Nutrition variant	Regression equation	Coefficient of determination	Multiple correlation coefficient
Variety Kolchuga			
Control	$Y = 155,86 - 6,56X_2 + 175,61X_3 - 4,09X_4$	0,969103328	0,984430459
$N_{30}P_{30}$ (background)	$Y = 0,007 + 0,083X_1 + 16,99X_3 - 0,39X_4$	0,994792455	0,997392829
Background + Escort-bio	$Y = -20,49 + 0,97X_1 - 3,21X_3 + 0,48X_4$	0,987441678	0,993701
Variety Zamozhnist			
Control	$Y = -24,36 + 0,62X_2 - 9,64X_3 + 0,54X_4$	0,988868	0,994419
$N_{30}P_{30}$ (background)	$Y = 176,77 - 6,25X_2 + 169,35X_3 - 4,72X_4$	0,989904559	0,994939475
Background + Escort-bio	$Y = -44,47 - 0,23X_1 + 10,63X_3 + 0,87X_4$	0,987511136	0,993735949

The Constructed table of variance analysis (*ANOVA* – table), has the following form:

Table 4. *ANOVA* – table (variance analysis table)

Source of variables	Degrees of freedom	Sum of squares	Dispersions (average squares)
Regressions	$k_1 = m - 1 =$ $= 4 - 1 = 3$	$SSR = 6{,}103131293$	$MSR = 2{,}034377098$
Residues	$k_2 = n - m =$ $= 5 - 4 = 1$	$SSE = 0{,}0319487$	$MSE = 0{,}031948707$
of total variable	$n - 1 =$ $= 5 - 1 = 4$	$SST = 6{,}13508$	$MST = 1{,}53377$

The coefficient of determination without taking into account the number of degrees of freedom:

$R^2 = 0{,}99479$ testifies that the variation of the yield by 99,48% determines by the variation of the ear length, the weight of grain from the ear and the 1000 grains weight.

Multiple correlation coefficient: $R = \sqrt{R^2} = \sqrt{0{,}99479} = 0{,}993701$ is a measure function of linear connection of dependent variable Y with independent variables X_1, X_3, X_4. Its value 0,993701 shows the close connection between corresponding indicators.

Using the ANOVA table we could define:

– the variance of the regression: $\hat{\sigma}_p^2 = MSR = 2{,}034377098$;

–unbiased estimate of the variance of the residues: $\hat{\sigma}_u^2 = MSE = 0{,}031948707$;

–standardized error of residues: $\hat{\sigma}_u = \sqrt{\hat{\sigma}_u^2} = \sqrt{0{,}031948707} =$;

–variance of the dependent variable (total variance) $\hat{\sigma}_Y^2 = MST = 1{,}53377$.

Partial elasticity coefficients:

$$E_{\frac{Y}{X_1}} = \frac{\dfrac{\partial \hat{Y}}{\partial X_1}}{\dfrac{\overline{Y}}{\overline{X}_1}} = \hat{a}_1 \cdot \frac{\overline{X}_1}{\overline{Y}} = 0{,}200949;$$

$$E_{\frac{Y}{X_2}} = \frac{\dfrac{\partial \hat{Y}}{\partial X_2}}{\dfrac{\overline{Y}}{\overline{X}_2}} = \hat{a}_2 \cdot \frac{\overline{X}_2}{\overline{Y}} = 4{,}938201;$$

$$E_{\frac{Y}{X_3}} = \frac{\frac{\partial \hat{Y}}{\partial X_3}}{\frac{\overline{Y}}{\overline{X}_3}} = \hat{a}_3 \cdot \frac{\overline{X}_3}{\overline{Y}} = -4{,}14113.$$

The calculated partial elasticity coefficients show when if the ear length increases by 1%, the yield of winter wheat would increase by 0.200949, provided that the remaining factors are stable, if the mass of grain from the ear increases by 1%, the grain yield would increase by 0.443943, provided that the remaining factors are stable, and if the 1000 grains weight increases by 1%, the yield would decrease by 4.14113, provided that the remaining factors are stable.

The total elasticity

$$A = \sum_{j=1}^{n} E_{\frac{Y}{X_j}} = 0{,}200949 + 4{,}938201 - 4{,}14113 = 0{,}998016.$$

The total elasticity shows when if all the factors taken into account increase simultaneously by 1%, the yield of winter wheat would increase by 0.998016.

Check the statistical significance of the estimates of the model parameters t – Student's statistics. Let's determine the actual values t – statistics: $t_{\hat{a}_0} = 0{,}00196129;\ t_{\hat{a}_1} = 0{,}113124165;\ t_{\hat{a}_3} = 4{,}244929172;\ t_{\hat{a}_4} = -2{,}283886522.$

The table value t – criterion for the degree of freedom $k = k_2 = 5$ and the significance level $\alpha = 0{,}05$ is equal $t_{\text{табл}} = t_{0,05;5} = 2{,}57.$

As $t_{\hat{a}_3} > t_{\text{табл}}$, as the parameter a_3 of the model is statistically significant, therefore the parameter x_3 significantly impacts on the dependent variable Y. As $t_{\hat{a}_1} < t_{\text{табл}}$, $t_{\hat{a}_4} < t_{\text{табл}}$ and $t_{\hat{a}_0} < t_{\text{табл}}$, so corresponding parameters of the model are statistically insignificant. When if to decrease the confidence level, for example $\alpha = 0{,}1$, so $t_{\text{табл}} = 2{,}015$. And it would prove that the 50% confidence level validates the significance of the parameter a_4.

Let's check by F – criterion of Fischer the adequacy of the econometric model to actual data, such as the hypothesis of significance of connection between independent variables and the dependent variable $F_{\text{факт}} = 63{,}61635$ The table value for the specified confidence level $\alpha = 0{,}05$ and the number of degrees of freedom $k_1 = 2$ і $k_2 = 3$: $F_{\text{табл}} = F_{0,05;2;3} = 9{,}552$.

As $F_{\text{факт}} > F_{\text{табл}}$, so we decline the null hypothesis and with the specified probability $p = 0{,}95$ the econometric model would be consider to be adequate to actual data, therefore the hypothesis of significance of connection between independent variables and the dependent variable should be proved.

Checking the accuracy of the econometric model by the average relative approximation error $\bar{\varepsilon} = \dfrac{1}{n} \sum\limits_{i=1}^{n} \left| \dfrac{y_i - \hat{y}_i}{y_i} \right| \cdot 100\% = 1{,}53 < 10\%$, so it would testify of the high quality of the model.

That would be illustrated by Figure 2 as the insignificant deviation of y_i and $\hat{y}_i$ could be observed.
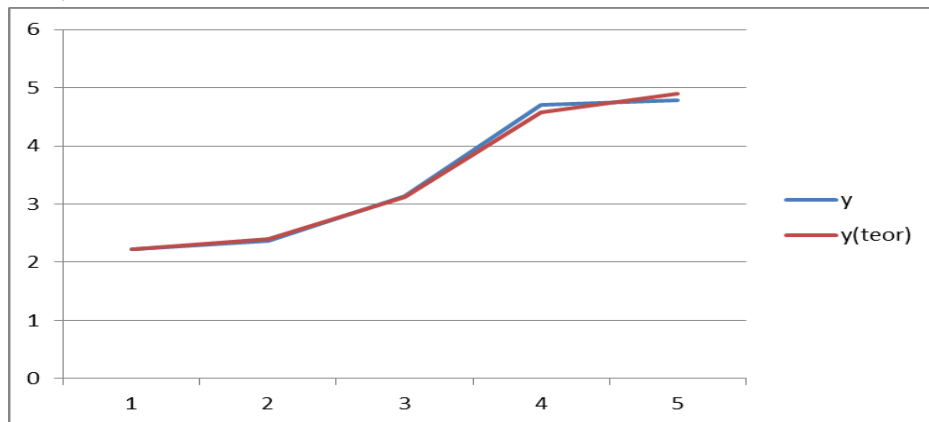

Figure 2. Diagrams of actual data and line of regression

So, the model is built with precision $\alpha=0{,}05$. For further research possible directions include developing a better model structure with less computation time and complexity, using some hybrid algorithms to build the embedded model, and using parallel algorithms.

In the process of research there is a need on the basis of available information about the yield to establish a statistical pattern for this set of observations. At the same time, the main point is to determine the factors affecting its level, in particular the influence of soil and climatic conditions, plant nutrition, economic indicators of crop cultivation. To that end, the researchers use various methods of economic analysis, in particular the method of analytical groupings, correlation and regression analysis, index method, etc. (Oprah, 2011; Kiani and Agahi, 2016).

Crop selection is influenced by many factors like the weather, soil type, market, etc. Weather and soil type are the major factors which affect on the crop yield. Crop yield prediction helps the farmers in the selection of the crop for plantation. Crop yield can be accurately predicted by considering the parameters like the soil type, amount of rain, crop characteristics, etc. Results show that the C-ANN model performs better with a higher R2 statistic and a lower percentage prediction error than the MLR and D-ANN models on the test dataset. Prediction of crop yield is very important in the agriculture community. In this study wheat yield was predicted by considering its different parameters. Better wheat yield was predicted by using C-ANN model (Aditya Shastry et al., 2016).

Using an experiment on integrated nutrient management in the rice-wheat processing system, a regression analysis of the biological yield and yield index of rice and wheat was studied to assess the contribution of various vegetative and reproductive traits (Gupta and Sharma, 2013). Two-year data on both crops showed that plant height, the number of cultivators during harvesting, the length of the stem and grain on fibrin were crucial for biological yield and yield index.

CONCLUSION

Under the conditions of southern Steppe of Ukraine, the application of mineral fertilizers at a dose of $N_{30}P_{30}$ for pre-sowing cultivation and foliar fertilizing of winter wheat crops at the beginning of the resumption of spring vegetation and the stooling with Escort – bio and Organic D2 drugs ensures the formation of the highest rates of crop structure. According to the results of mathematical calculations, in the control version of the experiment, the number of grains in the ear, the mass of grain from the ear and the 1000 grains weight have the greatest impact on the yield of the winter wheat variety Kolchuga. When applying mineral fertilizers for pre-sowing cultivation in a moderate dose of $N_{30}P_{30}$ and fertilizing during the growing season with the drug Escort-bio, there is a strong correlation between the yield and the length of the ear, the weight of the grain from the ear and the 1000 grains weight. The same dependence is observed in the variety Zamozhnist. For further research, possible directions include developing a better model structure with less computation time and complexity, using some hybrid algorithms to build the embedded model, and using parallel algorithms.

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