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ON PROBLEM OF ESTABLISHING THE INTENSITY LEVEL OF CROP VARIETY AND ITS YIELD VALUE SUBJECT TO THE ENVIRONMENTAL CONDITIONS AND CONSTRAINTS

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Abstract

The article focuses on the method of determining the level of intensity of an agricultural crop on the example of sunflower hybrids under the conditions of a particular farm, taking into account the quantitative impact of weather conditions on crop yields. It has been proved that the level of intensity of any new variety or hybrid is of great relevance both for planning the crop cultivation and evaluating the results of production activities. It is understood that the value of this indicator is defined as the ratio between the actual crop yield for three - five years and the standard or calculated one. This statement of the problem assumes that the average value of both weather conditions and crop yields for these years will be close to the average weather conditions in this area. The standard crop yield is calculated and, in general, comprised of yield that may be formed at the expense of natural soil fertility and the direct effect and aftereffect of organic and mineral fertilizers. It has been established that in case of the analysis of agricultural crop yields in the industrial sowing, when the number of years (repetition) is insufficient under one or another condition, it is possible to use a special method of assessing the quantitative impact of weather conditions on crop yields (V.D. Dmytrenko, A.M. Poliovyi). Its essence lies in the fact that any deviation of weather conditions from the optimal values for all growing periods leads to a decrease in the productivity coefficient or the level of impact on crop yields. At the same time, ultimately all the definitions and calculations should be recalculated based on the average data of weather conditions of the area of impact of a particular weather station. From the point of view of environmental constraints, it is necessary to maintain a deficit-free balance of humus and basic fertilizer element.

Key words: *yield planning, crop modelling, sunflower, hybrid intensity.*

INTRODUCTION

One of the important factors, which influence the yields of agricultural crops, is the weather conditions (Pirttioja et al., 2015). It should be noted that not only crop yields (Ray et al., 2015; Zhang et al., 2013), but also the efficiency of the use of resources, in particular nutrients from soil and fertilizers (Ryan et al., 2012), undergo certain changes under different weather conditions.

In turn, atmospheric precipitations and air temperature during the growing period of crops have a significant impact on crop yields as well (Högy et al., 2013). Results of researches show that crop yields were greatly influenced by the weather conditions of the agricultural year, but that new crops hybrids and sorts can be more resistant to draught or flooding, desease or insects damage (Dima, 2018; Singh et al., 2014; Delibaltova Dallev, 2018). There have been concerns about the possible yields of high productive hybrids or crops in different soil and climatic zone. The use of more intensive varieties of agricultural crops requires the development of crop cultivation technologies, in particular, the fertilizer system that has a direct impact on the qualitative characteristics of the soil (Tsvetkova and Saranenko, 2010; Jones, 2012) and, in particular, the balance of humus (Götze et al., 2016; Konieczna and Roman, 2014) and nutrients in the soil (Körschens et al., 2013). Modern techniques offer different ways of sowing with different row spacing and fertilization conditions.

At the same time, it bears mentioning significant negative changes in the qualitative indicators of the soil as a result of human activities, namely, farming operation (Bezrodnova and Loza, 2006; Brock et al., 2013) and various types of contamination (Romaniuk et al., 2016). Irrigation treatments also influence on yield parameters of different crops (Rafiei et al., 2013; Fedorchuk, 2016). Toshichika et al. (2017), using long period crop yield data, made underpin the importance of ambitious climate mitigation targets for sustaining yield growth worldwide.

Over the world researchers calculate statistical yield forecast models and built respectively regressions using composite weather variables (Singh et al., 2014; Basso et al., 2014). Results of reseaches performed by Černý et al. (2013) showed statistically significant influence of year weather conditions, genetic material and the application of preparations on sunflower achenes yield.

Value of resistance of hybrids are rising due to the importance of hybrid selection in modern sunflower production. So it was decided to calculate the intensity of crops.

The intensity of the development of agriculture as a whole is characterized by the two components: the level of intensity of technologies (*LiT*) and the level of intensity of variety or hybrid of an agricultural crop (*LiV*) that in totality determines the level of agricultural technology of crop cultivation (*La*). It is beyond argument that being aware of the actual value of any of the above mentioned indicators is of significant practical importance. Thus, if it is referred to the intensity of technology (*LiT*), it can be clearly argued about the need for economic justification of one or another technological measure by comparing the additional costs of its implementation and the effect of application.

It has been established that the intensity of technology should be understood as the most optimal predecessor, the timeliness, promptness and quality of conducting technological operations, the application of the most effective forms of fertilizers, various types of growth-promoting agents, the methods of their use, etc. It is also conceivable that the intensity of technology may include seedling vigor and timeliness, weed infestation of crops, incidence of pests and diseases during the cropping season. All this points up the fact that the ratio of the yield of one and the same crop variety, pursuant to the application of the same level of fertilizer according to the new and existing technologies, may quantitatively characterize the technology as follows (Kharchenko and Sobko, 2016):

$$LiT = \frac{Y_{nt}}{Y_{et}} \quad (1)$$

Ynt and Yet is the crop yields under new and exist technologies. The quantitative characteristics of the intensity of crop variety or hybrid are understood as the ratio between actual crop yields *(Y_a)* and standard crop yields (Y_s) ((Kharchenko and Sobko, 2016):

$$LiV = \frac{Y_a}{Y_s} \quad (2)$$

It is beyond argument that the most dynamic indicator of the development of crop production at this stage is a new variety or hybrid, which is characterized by the yield capacity higher than that of analogues. The mere fact of the advantage of this indicator makes it clear that this variety is more intensive, or to be exact, more aggressive. The highest yield capacity can be explained only by the coefficient of use of basic nutrients both from the soil and fertilizers that is higher than that of analogues. The practical need for being aware of this indicator is determined by the subsequent need to establish the rate of fertilizer usage for the planned yield level, and the actual efficiency of fertilizers upon the evaluation of the obtained yields.

Special attention in the above dependence (2) is given to the so-called standard crop yield. This crop yield constitutes its calculated value with the known values of efficiency of using resources of the main factors (moisture, food, etc.). At present, one of the most studied aspects is the efficiency of using the nutrition resource, which is proposed to be taken into account in further calculations.

First of all, it should be noted that this yield capacity is composed of the two components – the yield, which is formed due to the natural soil fertility (without fertilizers) and the yield growth due to the application of fertilizers (organic and mineral), as well as the aftereffect of applying fertilizers in the predecessor. In fact, this yield is calculated by one or another method using the reference data or by the standard return of fertilizers and ball bonitet of the soil (return method), or by the coefficient of use of the main elements of the soil and fertilizers (balance method). With regard to the above mentioned, the values of these constants are known to be valid only for those varieties or hybrids, for which they have been obtained. Thus, the values of these indicators for more productive new varieties or hybrids will be somewhat different that can be determined by the indicator of variety intensity (*LiV*).

On the other hand, there is no doubt that the level of actual yields, and hence the level of actual efficiency of the use of main elements from the soil and fertilizers will depend significantly on weather conditions (Maltais-Landry and Lobell, 2012), or rather their compliance with the requirements of an agricultural crop. In general, it can be argued that a mean value for at least three or five years should be obtained in order to be provided with the reliable data on the level of intensity of a crop variety or hybrid. It will be understood that in this case, the mean value of yield capacity and the level of the variety intensity somehow assumes the mean value of weather conditions for this period.

When analyzing the results of production activities, there is often a situation when a different variety or hybrid is annually grown as a result of the influence of advertising or personalistic decisions. This state of affairs overcomplicates the procedure for assessing a new variety or hybrid by the indicator of intensity.

Proceeding from the above mentioned, it should be noted that at present there are a number of scientific developments, the implementation of which enables to determine the quantitative impact of the actual weather conditions on the actual yield of some crops in terms of their compliance with the necessary requirements.

METHOD OF DETERMINATION OF HYBRID INTENSITY

The quantitative assessment of the impact of weather conditions on crop yields can be determined by a special method (Kharchenko and Sobko, 2016; Poliovyi, 2007). The essence of this method, first of all, is that the vegetation cycle of a crop is divided into separate periods with the weight factors (α_i), which in fact show the percentage of the impact of this cycle on the formation of the yield capacity established for each of these periods. The proposed values of these factors correspond to the optimal values of temperature (*T°C*) and precipitations ($\sum A$, *mm*) and sum up to 1.0. In this case, any deviation of the actual data from optimal leads to a decrease in the values of these factors. In the case of optimal values of these indicators, the maximum crop yield, the value of which is provided with the basic resources, is formed.

The vegetation cycle of sunflower is divided into five periods with the corresponding impact of each of them on the yield formation (Poliovyi, 2007; Lohvinov, 1976) (Table 1).

Table 1. Characteristics of sunflower vegetation cycle in the Forest-Steppe of Ukraine and optimal values of air temperature (T_O, °C) and precipitations (A_O, mm) (Poliovyi, 2007)

Periods of vegetative cycle	Months	Weight factors α_T	T_0, °C	A_0, mm
Presowing	XII-III	0.20	-5.0	180
Sowing	IV	0.05	7.6	40
Shoots - second pair of true leaves	V-VI	0.19	16.0	110
Bud formation - flowering	VII	0.19	19.0	80
Flowering - ripening	VIII	0.37	19.0	60
		$\sum\alpha_T$=1.00		

Therefore, the degree of impact on the sunflower yield during the development periods is different with the highest value in the phase of flowering-ripening (0.37), which falls on August, when the optimal average air temperature is 19.0°C, the optimal amount of atmospheric precipitations is 60 mm (Table 1).

Thus, according to this method, the actual weather conditions with the actual weight factor or performance factor $\sum\alpha_a$, with the known actual crop yield (Y_a), the maximum crop yield under the favorable or optimal weather conditions subject to the actual provision of nutrition resources could be as follows:

$$Y_{\max} = \frac{Y_a}{\Sigma\alpha_a}, \text{ cwt/ha} \qquad (3)$$

We have obtained the calculations made related to various agricultural crops during several years. This article presents an example of applying this method according to the results of sunflower cultivation under the conditions of

Agricor Holding LLC located in Chernihiv Region for the period of 2014 and 2015. It should be noted that every year different sunflower hybrids were grown under different weather conditions, where the fertilizer amount and, therefore, the standard and actual yields were different as well.

The assessment of weather conditions for these years has shown that the conditions in 2014 are close to favorable (reasonable crop losses are amounted to 16.6%), and the conditions in 2015 are significantly unfavorable and, especially, during the flowering–ripening period that causes crop losses in the amount of 36.4% (Table 2).

Table 2. Actual weather conditions of the sunflower vegetative cycle in the conditions of Pryluky WS and actual performance factors

Periods of vegetative cycle	Months	Weight factors α	Actual values				
			Precipitation A, mm	η(A)	T^0C	η(T)	S(A,T)*α=α_a
2014							
Presowing	XII-III	0.20	93.8	0.94	-0.5	0.71	0.135
Sowing	IV	0.05	28.3	0.99	9.5	0.88	0.44
Shoots - second pair of true leaves	V-VI	0.19	123.6	1.00	17.6	0.95	0.181
Bud formation - flowering	VII	0.19	56.2	0.98	21.9	0.85	0.164
Flowering - ripening	VIII	0.37	19.8	0.89	20.8	0.94	0.310
		∑=1,00					∑S(A,T)α= $\sum\alpha_a$ =0.834
2015							
Presowing	XII-III	0.20	133.5	0.99	-1.0	0.73	0.145
Sowing	IV	0.05	18.8	0.93	8.9	0.93	0.043
Shoots - second pair of true leaves	V-VI	0.19	247.5	0.80	17.2	0.97	0.147
Bud formation - flowering	VII	0.19	45.4	0.96	20.5	0.96	0.175
Flowering - ripening	VIII	0.37	5.0	0.35	20.3	0.97	0.126
		∑=1.00					∑S(A,T)α= $\sum\alpha_a$ =0.636

It is understood that such interpretation of possible yields as maximum (Formula 3) is insufficient, since the probability of favorable conditions can be quite low, and any planning, including the planning of the amount of fertilizers, is made for the average weather conditions. Thus, for the average weather conditions one should determine the level of their favorability for sunflower growing. The data presented in Table 3 show that the average weather conditions are close enough to favorable, and the productivity coefficient ($\sum\alpha_{CP}$) is equal to 0.978. This enables to determine the level of possible yields subject to the actual provision of nutrition resources under the average weather conditions depending on:

$$Y_{av} = Y_{MAX} \cdot \Sigma\alpha_{av}, \text{centner/ha} \quad (4)$$

The analysis of different levels of the yield of sunflower hybrids grown on the farm (Table 4) has shown that the actual yield levels, as well as the standard ones (different levels of fertilizers), are significantly different, with the hybrid NK Dolby (Cruiser) (in 2014) having significantly higher yields than NK Brio (Cruiser) (in 2015). However, given the significantly worse conditions of 2015, the calculations have shown that under the optimum (favorable) conditions the hybrid NK Brio (Cruiser) with the actual application of the same amount of fertilizers could have had substantially higher yield (38.2 cwt/ha) than the hybrid NK Dolby (Cruiser) (36.6 cwt/ha), while the standard levels of productivity and, therefore, the fertilizer amount have had the opposite values.

The results presented in Table 4 show that although according to the actual data the intensity level of NK Dolby (Cruiser) hybrid is higher than the intensity level of NK Brio hybrid (Cruiser) (1.67 versus 1.75). Taking into account the weather conditions, NK Brio hybrid (Cruiser) should be considered to produce higher yields since both for optimal and average conditions its intensity level is significantly higher than the intensity level of NK Dolby (Cruiser). At the same time, it is expedient to use in further calculations the indicators of the intensity level of 2.05 NK Dolby (Cruiser) and 2.54 NK Brio (Cruiser), respectively.

Table 3. Assessment of the impact of hydrothermal conditions on sunflower yield by average weather conditions (Pryluky W.S.)

Indicators	Presowing (XII-III)	Sowing (IV)	Shoots-second pair of true leaves (VVI)	Bud formation-flowering (VII)	Flowering-ripening (VIII)	Total for vegetation cycle
Standard weight factor (α)	0.20	0.05	0.19	0.19	0.37	1.00
Temperature, $(T)^0C$	-4.7	6.8	16.1	19.7	18.4	–
Coefficient of productivity by temperature η (T)	0.98	1.00	1.00	1.00	0.96	–
Precipitation, (A) mm	155	46	136	72	64	473
Coefficient of productivity by precipitation η (A)	1.00	0.99	0.99	1.00	1.00	–
Compatible productivity coefficient $\eta(T)\cdot\eta(A)$	0.98	0.99	0.99	1.00	0.96	
Coefficient of impact of conditions on yield $S(T,A)=\eta(T)\cdot\eta(A)\cdot\alpha$	0.196	0.049	0.188	0.190	0.355	0.978

Table 4. Actually expected values for optimum and average conditions of sunflower hybrid yields and their actual level of intensity, cwt/ hectar

Yield, c/ha				Intensity level (*LiV*)		
*Y*a (actual)	Y_{MAX}	*Y*av (average)	*Y*s (standard)	*LiVa*	LiV_{MAX}	LiV_{AV}
2014, NK Dolby Cruiser hybrid (*X* = 92 kg p.n./ha)						
30.53	**36.6**	**35.8**	**17.49**	**1.75**	**2.09**	**2.05**
2015, NK Brio Cruiser hybrid (*X* = 45 kg p.n./ha)						
24.3	**38.2**	**37.4**	**14.58**	**1.67**	**2.62**	**2.54**

It should be noted that such intensity values of hybrids are obtained with the technology implemented on the farm, that is, the existing level of its intensity. It is beyond argument that in the case of growing any of these hybrids during other years and on other farms, the obtained characteristics of hybrids might differ slightly from the above mentioned ones, and the magnitude of such deviations will depend primarily on the level of intensity of the technology.

The assessment made has convincingly shown that the impact of weather conditions as the environmental background condition on the crop yield is practically assured, and a high degree of study of this impact for a number of crops, including sunflower, enables to determine the magnitude of such impact (Poliovyi, 2007).

Thus, all of the above show that the level of intensity of the crop variety significantly affects the efficiency of fertilizers, that is, the more intensive the variety is, the less the amount of fertilizers for the formation of the accepted or planned yield could be. On the other hand, the value of this amount of fertilizers should be economically justified that under all other conditions is determined by the ratio of prices for fertilizers and products.

It should be noted that significant environmental constraints on the amount of mineral fertilizers and hence the crop yield (planned or programmed) are the condition of a deficit-free balance of basic nutrients (N P K) and humus for the period of crop cultivation. There is no doubt that the above conditions are the subject of instrumental research, more often for rotation, but the existing methodological framework enables to make such calculations as baseline for each growing season (Kharchenko, 2011).

It is understood that these constrains are not always unambiguous, thus, in this case it is advisable to determine their parity. From our point of view, the conditions of a deficit-free balance of humus as a background condition for the natural soil fertility should be considered to be the first constraint (Kharchenko et al., 2008).

From the point of view of practical application, it is proposed to make the following explanation. Thus, the calculations have established that to ensure a deficit-free balance of humus, the critical yield of sunflower, in which the humified mass of by-products (leaf-stem mass and roots) will not be less than its loss during mineralization, is equal to 41.6 centner/ha. The further research results also show that with ball bonitet of the soil (agrochemical) equal to 70 points under the average conditions, the required amount of mineral fertilizers for full mineral nutrition for NK Dolby hybrid (Cruiser) is 2.41 centner p. n./ha, NK Brio hybrid (Cruiser) - only 0.70 centner p. n./ha.

CONCLUSIONS

In case of the analysis of the results of the industrial sowing of agricultural crop for an insufficient period of years, it is proposed to assess the level of intensity of a variety or hybrid, taking into account the quantitative impact of weather conditions on yield, based on the average conditions in this area. At the same time, the planning of the yield value should be carried out taking into account environmental constraints and, above all, under the conditions of the deficit-free balance of humus.

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