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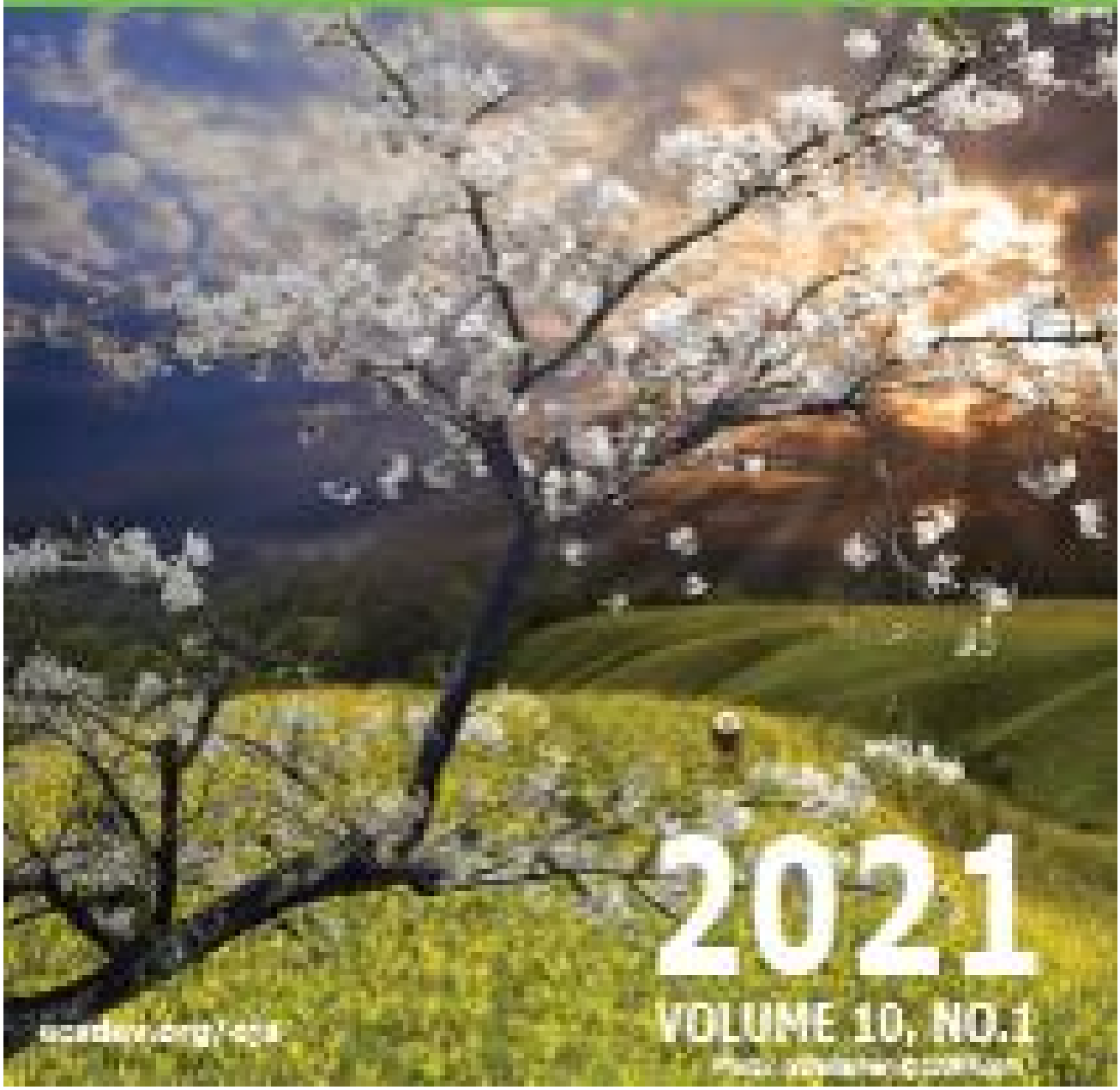

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The Modeling of the Production Process of High-Starch Corn Hybrids of Different Maturity Groups

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ABSTRACT
The article presents the results of mathematical modeling based on the construction and use of various images of the object, process or system. The research involves the study of the dependence of the level of productivity and valuable farming traits of corn hybrids in the form of mathematical models. Field research was carried out during 2011-2017 on the experimental fields of the Department of Crop Production, Breeding and Bioenergy Crops of Vinnytsia National Agrarian University, at the state enterprise "Research Farm "Kordelivske" of the Institute of Potato Production of the National Academy of Agrarian Sciences of Ukraine under conditions of the right-bank Forest-Steppe in accordance with the guidelines provided in "Methodology of Field Experiments in Corn". The use of computer technology, in particular, cluster analysis, from our point of view, allows us to approach the difficult task of improving the efficiency of the correct choice of hybrids and technologies to obtain the maximum level of bioethanol yield per unit area of maize hybrids. An ecological-genetic model of quantitative traits was used to study the phenotypic productivity of corn hybrids and to establish the influence on the formation of their traits. The construction of the model is based on the hierarchy of manifestation of productivity traits in ontogenesis and the correspondence of their manifestation in organogenesis. The model consists of three modules of traits including the resulting one and double-component that reflect phenotypic implementation of the genetic formula. The resulting traits are those that have environmentally stable correlation and the highest total impact on the final resulting trait, namely, the yield. According to the results of researches of mathematical models of the influence of weather conditions on the formation of phenotypic productivity of corn hybrids of different maturity groups, both general biological regularities and group differences of trait formation have been established. Thus, the analysis of the differences between the groups of early and mid-early corn hybrids, in general reveals that their growth and development are affected to a relative extent by the amount of effective temperatures, amount of precipitation and HTC. In fact, the maturity groups studied differ insufficiently, and the main differences can be observed only in the variability of the traits studied or the closeness of their relationships with each other. However, mid hybrids respond somewhat differently to environmental factors, which allows to develop the elements of adaptive cultivation technology for each maturity group. Based on the results of cluster analysis, cluster dendrograms were created using the odd-numbered group method with the determination of Euclidean distances.

Keywords: corn, hybrid, phenotype, mathematical model, productivity, valuable farming traits.

1. Introduction

A mathematical model is essentially one of the main components of the scientific methodology of research of the nature in general and the processes that occur during crop cultivation in particular. The basis of the mathematical model (Latin modulus – sample) is the construction and use of various images (representations, concepts) of the object, process or system in a certain form that differs from the form of their actual existence (Loos et al.,

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2003; Sogbedji et al., 2006; Comas et al., 2016). Formation of the concept of "model" and development of different models have always occupied an important position in the practical activity of the society, especially since it has begun to seek to understand the processes and phenomena occurring in the environment (Yang & Alley, 2005; Bulgakov et al., 2014; Bulgakov et al., 2019a; Bulgakov et al., 2019b; Kaletnik et al., 2020a; Kaletnik et al., 2020b). Effective forms of modeling are mathematical and simulation modeling, which reflect the most significant features of real objects, processes, phenomena and systems studied by various sciences, including Biology and Ecology.

To determine the similarities and differences of groups of economically valuable traits in the studied maize hybrids, cluster analysis is best, because this method, unlike most mathematical and statistical methods, has no restrictions on the type of objects studied. The cluster analysis method allows you to process large amounts of data. The peculiarity of this grouping is that objects belonging to one cluster are related to each other than objects from different clusters. This approach provides the analysis of the results in the form of a dendrogram, which is built on the basis of combining objects into clusters, using some degree of similarity or distance between objects.

When developing and applying mathematical and simulation models to study various natural systems and processes, including patterns of development of living systems and individual organisms and populations, the general principles and methods of mathematical modeling and forecasting are used as guidelines. At the present stage of agricultural development, the requirements for varieties and hybrids have changed because of the need to shift to adaptive agriculture due to global climate change (Prakash et al., 2019; Pinos et al., 2020; Parvej et al., 2020). Therefore, qualitative changes are needed for the experimental and mathematical support of technologies of crop cultivation in general and corn cultivation in particular. The systems approach is the consideration of variability from a single point of view, namely the manifestation of various forms of variability in the context of the functional integrity of macrosystems and agribiocenosis (Cargnelutti & Toebe, 2020; Ismagilov et al., 2020; Kandasamy et al., 2020). There can be observed a significant increase in the area under corn grown for grain in Ukraine and World and there is an urgent issue of increasing its yield and studying the possibility of its processing into biofuels. Given the significance of well-known scientific developments on the research of the problems of corn cultivation for grain, consideration of a comprehensive approach to assessing adaptive traits of hybrids, elements of the technology and features of starch accumulation in grain will enable to carry out qualitative assessment of the possibility of bioethanol production. Research of this issue is a relevant and decisive factor in the process of forming the most productive parameters of corn and has scientific and practical significance (Yanovych et al., 2017; Palamarchuk et al., 2018; Yanovych et al., 2018; Palamarchuk & Telekalo, 2018; Mazur et al., 2019; David et al., 2020; Du et al., 2020; Telekalo & Melnyk, 2020).

According to the studies, agribiocenosis is the level of functional organization of biological and ecological systems involved in production, which unfolds all the mechanisms of variability and the process of natural selection, the systemic manifestation of which should be taken into account during the selection process (Simons et al., 2020). Theoretical substantiation of adaptive selection is based on a system approach to the study and management of variability of traits and properties of macrosystems in the selection process. The emphasis is made on the variability, which is manifested in the real conditions of

functioning of plant macrosystems (Alvarez et al., 2019; Agackesen & Oktem, 2020; Ali et al., 2020). In the field conditions, crops are affected by both abiotic and biotic factors (Kolisnyk et al., 2020; Ramos et al., 2020). Moreover, the elements of the technology can be developed, improved, adapted for the cultivation of specific corn hybrids in particular agri-climatic conditions (Biberdzic et al., 2018; Baldotto et al., 2019; Cabaroiu et al., 2019). But as for the factors influencing the environment, it is almost impossible to influence the course of these processes. Instead, mathematical modeling should be used to ensure effective analysis of the rate of response of corn plants to the effects of adverse environmental factors (Barbosa et al., 2019; Bernhard & Below, 2020).

First of all, it is interesting to use mathematical models to determine critical influence of climatic conditions on the growth and development of corn hybrids of different maturity groups (Dias et al., 2019; Filip & Marin, 2019; Jaksic et al., 2019; Cooper et al., 2020). Determination of the influence rate is calculated on the basis of the method of correlation galaxies, and their ecological and genetic versions presented by Litun (2007) have been selected as the basic version of the mathematical model. Comprehension of the processes of formation of vegetative and generative organs of corn plants, the sequence of qualitative changes in the plant organism and growth processes will enable to manage the productive component of corn yield (Lima et al., 2020; Luo et al., 2020; Ma & Zheng, 2020; Mylonas et al., 2020). Promotion or minimal intervention in the plant organism during the stages of organogenesis minimizes the risks of abnormalities and reduction of the productivity of agricenosis in general. At any stage of organogenesis, a negative effect of both biotic and abiotic factors is possible, which can disrupt or slow down the entire subsequent process of formation of generative organs. This effect can be especially noticeable in the early stages of plant development (up to the 11th leaf). A significant influence of the growing season duration on the indicators of the linear size of plants, height of ear placement has been established. However, the duration of the growing season itself, even of the same hybrid, can vary depending on the heat and moisture supply under conditions of a particular year. The objective of our research was to study the dependence of the level of productivity and valuable farming traits of corn hybrids in the form of mathematical models.

2. Materials and Methods

Field research was carried out during 2011-2017 on the research field of the Department of Plant Cultivation, Breeding and Bioenergy Crops of Vinnytsia National Agrarian University, at the state enterprise "Research Farm "Kordelivske" of the Institute of Potato Production of the National Academy of Agrarian Sciences of Ukraine under conditions of the right-bank Forest-Steppe. Field experiments were carried out in accordance with the guidelines presented in the Methodology of Field Experiments in Corn (Tandzi & Mutengwa, 2020; Tucker et al., 2020).

The research trials were conducted on deep mid loamy black forest soils. The content of humus (according to Tiurin) in the arable layer was 4.60%. Soil reaction was pH (salt) 5.7; weighted average: hydrolytic acidity was 40 mg.-eq. per 1 kg of soil; the amount of absorbed bases was 158 mg.-eq. per 1 kg of soil (according to Kappen-Gilkovitz); the degree of saturation of the bases was 82.3%. Agriphysical properties: soil density was 1.2 g/cm^3. The soils contained easily hydrolyzed nitrogen (according to Cornfield) of 106 mg per 1 kg of

soil, mobile phosphorus and exchangeable potassium (according to Chirikov) 186 and 160 mg per 1 kg of soil, respectively. Soil reaction was pH (salt) 5.7 (close to neutral), soil density was 1.2 g/cm^3. Soil fertility potential was estimated to be increased. Agrichemical assessment of these soils comprised 68 points, and ecological agrichemical assessment was 63 points.

Climatic conditions over the years of study were characterized by some difference. Thus, in 2011, initially cold weather with frosts in the first and second decade of April restricted the first (early) sowing period, so it was held on April 25, 2011. In May, there was observed an increase in temperature indicators and rainfall deficiency, which significantly affected seed germination in the second and third sowing period. Further on, the climatic conditions of 2011 differed little from long-term ones and were favorable for corn growth and development. Rapid spring of 2012 and unusually high temperatures of April provided unfavorable agri-climatic conditions for corn development. From May till the second decade of August, there was observed moisture deficiency, as evidenced by a significant deviation of the amount of precipitation during this period from the average long-term ones. In 2013, insufficient temperatures and significant rainfall restricted early sowing, especially in the first decade of April. Soil and climatic conditions were characterized by certain diversity with a special emphasis on the arid conditions of 2015 when the temperature exceeded 42 °C. In 2014, 2016 and 2017, climatic conditions appeared to be the most favorable for the growth and development of corn plants.

In the process of cluster analysis used data obtained on the basis of field studies, which included the following economically valuable features for which the analysis of maize hybrids: (morphological features – total leaf area, flag leaf area, area of pumped leaf, plant height, height of cobs, leg length, number of coils, transpiration intensity, chlorophyll content, content in the vegetative mass of nitrogen (N), phosphorus (P), potassium (K) and zinc (Zn); elements of crop structure – number of rows of grains (KRZ), number of grains in a row (KZR), weight of 1000 seeds, sum of linear grain sizes, number of cobs per plant, yield, grain moisture, starch content, starch yield per unit area and bioethanol yield from ha^{-1}), the duration of the periods "sowing-seedlings", "seedlings – flowering cobs", "flowering cobs – full maturity", "seedlings complete – maturity ". In fact, all the economically valuable features of the maize hybrids we studied were used for the analysis to study the possibility of producing alternative energy sources.

The experiments provided economic and biological evaluation of corn hybrids depending on the sowing date, seed size and seeding depth, foliar nutrition with microfertilizers. Field and laboratory methods of the study of the corn hybrid material were used in the research. The estimated area of the sites under hybrids was 10.5 m^2. Replication in the experiments with hybrids was triple. The sites were located by the method of randomized blocks. An ecological-genetic model of quantitative traits was used to study the phenotypic productivity of corn hybrids and to establish the influence on the formation of their traits. The model was constructed on the basis of the hierarchy of manifestation of productivity traits in ontogenesis and the correspondence of their manifestation in organogenesis. Since the stages of implementation in the phenotype of a quantitative trait reflect the stages of complication of the genetic system, the relationship between the components of the model can be considered as an indicator of the dynamic order of interaction between the elements of the genetic system [5. Sowing was carried out with an upgraded seeder SUPN-8 under the seeding rate of 75 thousand seeds per hectare. Hybrids of domestic selection (Kharkivskyi

195MV and Pereiaslavskyi 230SV) and hybrids of Monsanto Company DKC 2870, DKC 2960, DKC 2949, DKC 2787, DKC 2971, DKC 3476, DKC 3795, DKC 3472, DKC 3420, DKC 391, DKC 3871, DKC 3511, DK 440, DKC 4964, DKC 4626, DK 315 were used as the most productive ones of three groups of maturity, including early, mid-early and mid hybrids. The model consists of three modules of traits, namely the resulting one and double-component that reflect phenotypic implementation of the genetic formula. The resulting traits are those that have ecologically stable relationships and the highest total contribution to the final resulting trait, i.e. the yield (Litun et al., 2004; Litun et al., 2007; Zermas et al., 2020).

3. Results and Discussion

Parameters of the model of influence of weather conditions on the formation of phenotypic productivity of early corn hybrids are shown in Figure 1.

The model consists of three modules of traits, in particular, the resulting and double-component that reflect the phenotypic implementation of the genetic formula. With the help of modules it is possible to provide quantitative assessment of the specific gene organization of the trait of a particular genotype. The resulting traits are those that have environmentally stable links and the highest total impact on the final resulting trait, i.e. the yield. An important parameter of the influence on the traits studied is not only their interaction with each other but also weather conditions that may actually limit or, on the contrary, contribute to the manifestation of specific traits in corn hybrids. Therefore, there was determined correlation between the weather conditions corresponding to specific periods of plant growth and development and the traits of phenotypic productivity.

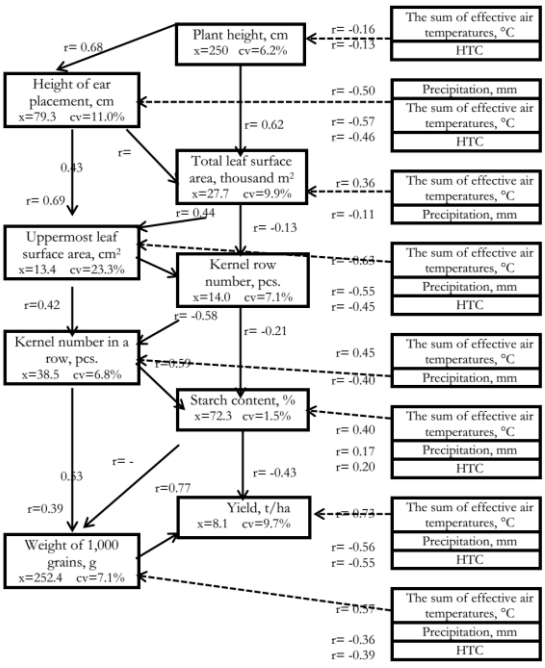

Figure 1: Model of the influence of weather conditions on the formation of phenotypic productivity of early corn hybrids

It was found that the average height of early corn hybrids in the experiment was 250 cm and the sum of effective temperatures and HTC had a weak effect on the formation of this trait. However, the studied indicator significantly affected the total leaf surface area (r = 0.62) and the height of ear placement (r = 0.68). The height of ear placement, in its turn, depended not only on the total plant height but on the leaf surface area (r = 0.43) and uppermost leaf area (r = 0.69). The height of ear placement was influenced by the amount of precipitation (r = -0.50), the sum of effective air temperatures (r = -0.57) and HTC (r = -0.46).

The total leaf surface area in early corn hybrids was formed on average in experiment at the level of 27.7 thousand m²/ha and, despite the established patterns of correlation with the total plant height, it determined the formation of the uppermost leaf surface area (r = 0.44) and slightly influenced the formation of the kernel row number in the ear (r = 0.13). The sum of effective air temperatures (r = 0.36) had the most effective effect on the formation of the leaf surface area.

The uppermost leaf surface area of the studied early corn hybrids affected kernel number in the row (r = 0.42) and was formed under the influence of the sum of effective temperatures (r = -0.63), amount of precipitation (r = -0.55) and HTC (r = -0.45). The kernel row number in early corn hybrids is a genetically determined indicator (14 ones), which varies quite insufficiently (coefficient of variation of 7.1%) under the influence of cultivation conditions. Therefore, in our studies, there was established no significant effect of the cultivation conditions on this trait.

At the same time, it was investigated that such trait as the kernel number in a row (38.5 kernels) depended on the influence of the sum of effective air temperatures (r = 0.45) and the amount of precipitation (r = -0.40). Formation of this indicator was also influenced by the kernel row number (r = -0.58) and this feature determined the total starch content in corn grain (r = 0.59). Starch content in corn grain is formed not only under the influence of biological features of the studied early corn hybrids but it is also determined by the cultivation conditions, namely the sum of effective temperatures (r = 0.40), amount of precipitation (r = 0.17) and HTC (r = 0.20).

Starch content negatively correlates with the yield (r = -0.43), which corresponds to the general biological ideas concerning the cost of high starch content formation as well as the level of corn productivity. At the same time, such indicator as the weight of 1,000 seeds is negatively correlated with the seed starch content (r = -0.53) and positively correlated with corn yield (r = 0.77).

This feature is also influenced by the sum of effective temperatures (r = 0.57), amount of precipitation (r = -0.36) and HTC (r = -0.39). On average over the years of research, early corn hybrids form the yield of 8.1 t/ha and this feature is significantly influenced by such factors as the sum of effective temperatures (r = 0.73), amount of precipitation (r = -0.56) and HTC (r = -0.55).

Graphical parameters of the influence of weather conditions on the formation of phenotypic productivity of medium-early maize hybrids are shown in Figure 2.

According to the results of the research it was determined that the average height of mid-early hybrids of corn in the experiment was 268 cm and the formation of this trait was influenced by the sum of effective temperatures (r = -0.47) and amount of precipitation (r = 0.12). In addition, the studied trait is moderately correlated with the total leaf surface area (r = 0.36) and significantly correlated with the height of ear placement (r = 0.69).

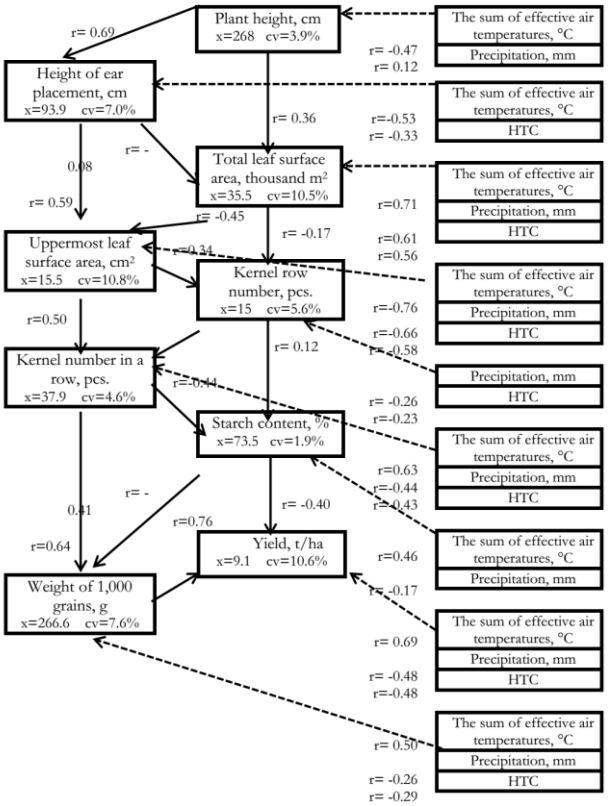

Figure 2: Model of the influence of weather conditions on the formation of phenotypic productivity of mid-early corn hybrids

The height of ear placement (93.9 cm), in its turn, depended not only on the total plant height but on the uppermost leaf surface area (r = 0.59) as well. The height of ear placement was influenced by the sum of effective air temperatures (r = -0.53) and HTC (r = -0.33). It is found that the leaf surface area in mid-early corn hybrids on average in the experiment was 35.5 thousand m²/ha and in addition to the patterns of correlation with the total plant height it depended on the size of the formed uppermost leaf surface area (r = -0.45) and, in its turn, it weakly affected the formation of the kernel row number in the corn ear (r = -0.17). However, as for climatic factors, the sum of effective air temperatures (r = 0.71), amount of precipitation (r = 0.61) and HTC (r = 0.56) had the most effective influence on the formation of the leaf surface area.

The area of the uppermost leaf in mid-early corn hybrids was formed under the influence of the sum of effective temperatures (r = -0.76), amount of precipitation (r = -0.66) and HTC (r = -0.58). In its turn, this feature also influenced the formation of the kernel row number (r = 0.34) and the kernel number in a row (r = 0.50).

Similarly to early corn hybrids, kernel row number in mid corn hybrids is also a genetically determined indicator (15 pcs.), which varies quite insufficiently (coefficient of variation 5.6%) under the influence of cultivation conditions. Therefore, in our studies, only the amount of precipitation (r = -0.26) and HTC (r = -0.23) had a weak effect on this feature.

However, it was found that such trait as the kernel number in a row (37.9 pcs.) depended much more sufficiently on the influence of the sum of effective air temperatures (r = 0.63), amount of precipitation (r = -0.44) and HTC (r = -0.43). This indicator interacted with the mass of 1,000 grains under significant level of correlation (r = 0.64) and with the starch content under correlation (r = -0.44).

Similarly to early group of corn hybrids, it was also determined that in mid-early corn hybrids the starch content in corn grain is formed not only under the influence of biological features of the studied early corn hybrids but it is also determined by the cultivation conditions, in particular, the sum of effective temperatures (r = 0.46) and amount of precipitation (r = -0.17).

In addition, this trait negatively correlates with the yield (r = -0.40) and weight of 1,000 grains (r = -0.41). Consequently, the obtained patterns fully correspond to the general biological ideas concerning the energy complexity of the formation of both high starch content and the level of corn plant productivity.

According to the data obtained, the weight of 1,000 seeds is negatively correlated with the starch content in seeds (r = -0.41) and positively correlated with corn yield (r = 0.76), which additionally confirms the above-mentioned patterns. Formation of the trait studied is also influenced by the sum of effective temperatures (r = 0.50), amount of precipitation (r = -0.26) and HTC (r = -0.29).

According to the results of modeling of mid-early corn hybrids, it was found that they formed an average yield of 9.1 t/ha over the years of research and this feature was significantly influenced by such factors as the sum of effective temperatures (r = 0.69), amount of precipitation (r = -0.48) and HTC (r = -0.48).

Analysis of the differences between the groups of early and mid-early corn hybrids reveals that general their growth and development are influenced to a correlative extent by the sum of effective temperatures, amount of precipitation and HTC. In fact, the maturity groups studied differ insufficiently, and the main differences are observed only in the variability of the traits studied or the closeness of their relationships with each other.

Parameters of the model of the influence of weather conditions on the formation of phenotypic productivity of mid corn hybrids is graphically represented in Figure 3. In the experiment, the average height of mid corn hybrids was 275.5 cm, which corresponded to the maximum parameters compared to other maturity groups. However, the level of formation of this trait was influenced by the sum of effective temperatures (r = -0.23) and HTC (r = -0.17). In addition, the studied indicator had a weak correlation with the total leaf surface area (r = -0.10) and significantly affected the height of ear placement (r = 0.56).

Studies on the height of ear placement revealed that in its turn it depended not only on the total plant height but on the leaf surface area (r = -0.50) as well as uppermost leaf surface area (r = 0.32). The height of ear placement was influenced by the amount of precipitation (r = -0.55), the sum of effective air temperatures (r = -0.61) and HTC (r = -0.54). It was found that the total leaf surface area in mid corn hybrids of corn averaged 38.3 thousand m^2/ha and had a significant level of correlation with the area of the uppermost leaf (r = -0.51). The sum of effective air temperatures (r = 0.74), the amount of precipitation (r = 0.64) and HTC (r = 0.58) had the most effective influence on the formation of leaf surface area.

The uppermost leaf surface area in mid corn hybrids influenced the formation of the kernel number per row (r = 0.47) and kernel row number (r = 0.34). This trait was formed under

the influence of the sum of effective temperatures (r = -0.78), amount of precipitation (r = -0.47) and HTC (r = -0.34).

Kernel row number in mid corn hybrids, despite its genetic predisposition (16 pcs.) and rather insignificant variability (3.0% coefficient of variation) still depended more on the influence of the cultivation conditions than in other corn maturity groups. Thus, this trait was influenced by the amount of precipitation (r = -0.30) and HTC (r = -0.26). Kernel number per row (40.7 pcs.) affected the formation of the weight of 1,000 seeds (r = 0.29) and slightly influenced starch content (r = -0.14) and, in its turn, depended on the influence of the sum of effective air temperatures (r = 0.59), amount of precipitation (r = -0.48) and HTC (r = -0.45). Starch content of the studied mid corn hybrids depends on the influence of the cultivation conditions, in particular, the sum of effective temperatures (r = 0.46) and the amount of precipitation (r = -0.13). Starch content negatively correlates with the yield (r = -0.42) and weight of 1,000 corn grains (r = -0.66).

The weight of 1,000 seeds positively correlates with the yield of mid corn hybrids (r = 0.86). The trait studied is also influenced by such parameters as the sum of effective temperatures (r = 0.43), amount of precipitation (r = -0.22) and HTC (r = -0.24). On average over the years of research, mid corn hybrids form the yield of 7.7 t/ha and this trait is influenced by such factors as the sum of effective temperatures (r = 0.43), amount of precipitation (r = -0.22) and HTC (r = -0.24).

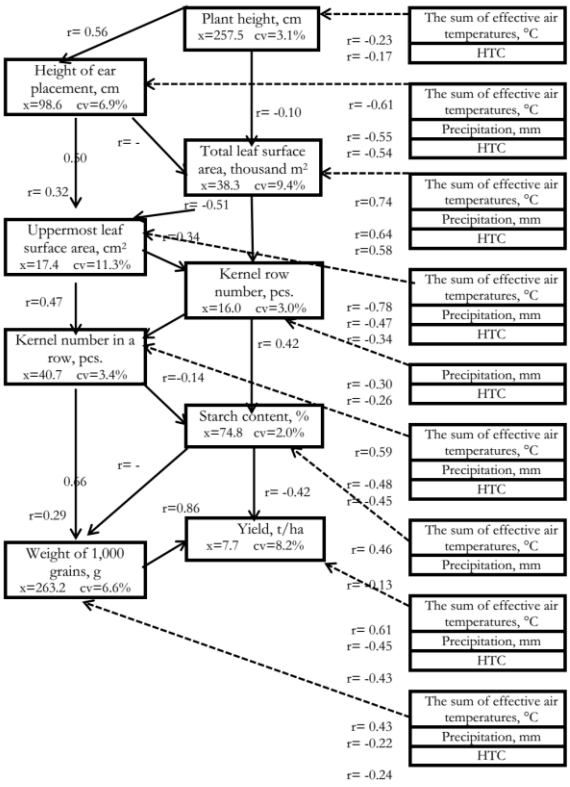

Figure 3: Model of the influence of weather conditions on the formation of phenotypic productivity of mid corn hybrids

Clustering of early-maturing maize hybrids by a set of economically valuable traits, by studying the influence of fraction and depth of seed wrapping is shown in Figure 4.
The rest of the studied hybrids at sowing by different fractions of seeds and the depth of its wrapping are adjacent to the above clusters, but generally lie far from them to speak of a full measure of identity in the formation of economically valuable traits.
Indicators of graphical construction of clusters of medium-early hybrids of corn on a set of economically valuable features, for studying the influence of fraction and depth of seed wrapping are shown in Figure 4.

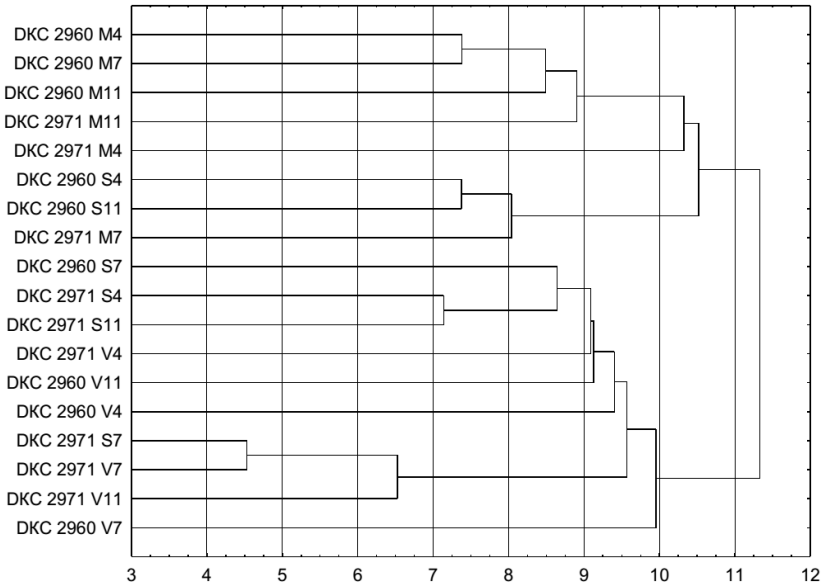

Figure 4: Clustering of early-maturing maize hybrids according to a set of economically valuable traits, for studying the influence of the fraction and depth of seed wrapping

In fact, the clustering of maize hybrids by a set of economically valuable traits, by studying the influence of the fraction and the depth of seed wrapping allows to distinguish similar in influence on different hybrids of the experimental factors. After all, sowing with a small fraction of seeds, in addition to the variant of the hybrid DKC 2971 for sowing to a depth of 7-8 cm falls into one cluster. Therefore, in this case, shallow seeds determine the growth and development of plants and cannot be compensated by a less deep wrapping of seeds. Thus, the growth and development of plants in the initial stages of the growing season significantly depend on the reserves of nutrients concentrated in the seeds. It can be argued that the dependences obtained by us are confirmed in the works of other researchers and belong to the general biological (non-varietal) patterns.
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Indicators of graphical construction of clusters of middle-early hybrids of corn on a set of economically valuable features, for studying the influence of fraction and depth of seed wrapping are shown in Figure 5.

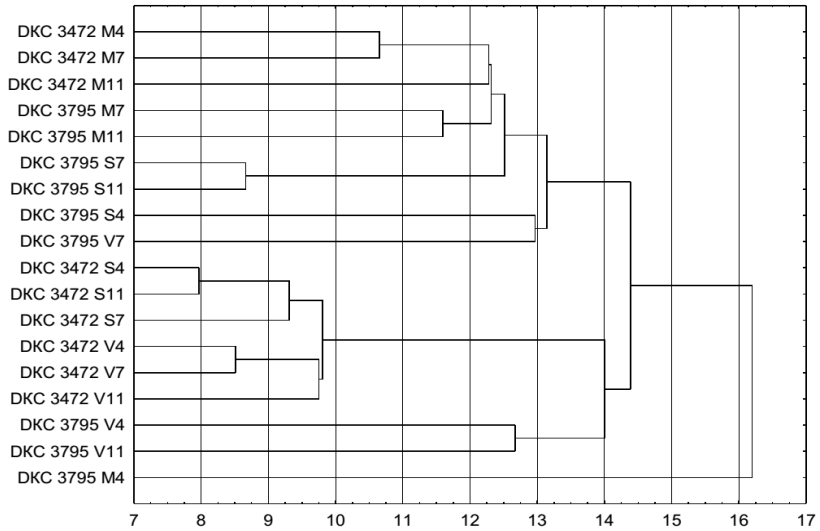

Figure 5: Clustering of medium-early maize hybrids by a set of economically valuable traits, by studying the influence of fraction and depth of seed wrapping

As for the peculiarities of the formation of economically valuable traits in medium-early maize hybrids, two pools of clusters can be distinguished among the studied variants.

The most similar cluster in terms of the set of features includes all variants of the experiment conducted with the hybrid DKC 3472 sown with medium and large seed fraction and at seed wrapping depths of 4-5, 7-8 and 10-11 cm. DKC 3472 benefits of medium and large seeds offset the negative impact of too shallow or deep seed wrapping. By analogy with the clustering of early-maturing, in middle-early hybrids, small fractions of seeds are similar in formation of a complex of economically valuable traits and are combined into one cluster. Thus, in this pool there are hybrids DKC 3472 and DKC 3795 for all depths of seed wrapping and shallow fraction and the latter for wrapping depths of 4-5 and 7-8 cm and the average seed fraction.

The division into clusters of medium-ripe hybrids of corn by a set of economically valuable traits, by studying the influence of the fraction and the depth of seed wrapping is presented in Figure 6.

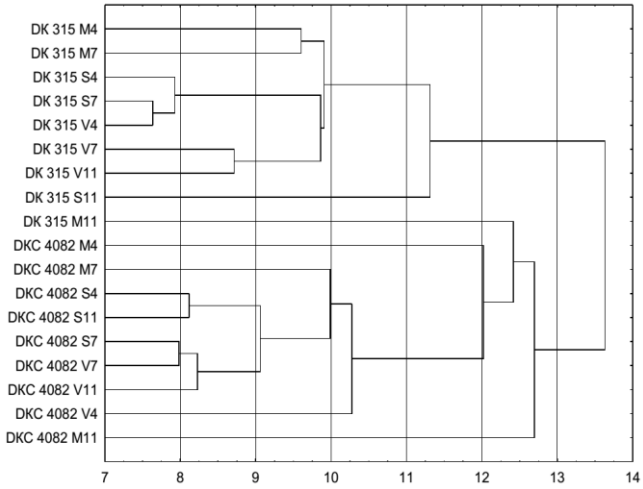

Figure 6: Clustering of medium-ripe corn hybrids by a set of economically valuable traits, by studying the influence of fraction and depth of seed wrapping

In medium-ripe hybrids, the regularity of clustering differs somewhat from the features we have found characteristic of early-ripening and middle-early hybrids. In fact, in this group of maturity, the biological features of the studied hybrids determined to a large extent the peculiarities of the formation of a set of economically valuable traits, rather than the characteristics of individual studied elements of cultivation technology. We believe that this is due in part to a longer growing season, which eliminates the delay in growth and development of plants at the beginning of the growing season.

Thus, according to the results of the analysis, it was found that the first cluster includes all variants of growing the hybrid DK 315 except for the variant of growing with a fine fraction of seeds and for seed wrapping depths of 10-11 cm.

The second cluster includes variants of growing the hybrid DKC 4082 with the exception of variants with growing a small fraction of seeds and wrapping depths of 4-5 and 10-11 cm, respectively.

On the other hand, the clear distribution of clusters by varietal characteristics indicates a good adaptive potential of hybrids DK 315 and DKC 4082. In fact, changes in the technology of growing these hybrids can be offset by plants in the process of their growth and development. Therefore, these hybrids forgive quite serious mistakes in cultivation technology, such as too deep sowing of seeds.

Accordingly, the analysis of clustering features of the studied hybrids by a set of economically valuable traits allows to draw conclusions about the recommendations for the technology of their cultivation and the creation of algorithms and mechanisms for predicting productivity based on predicting the response rate of plants and their growth and development.

4. Conclusions

The obtained mathematical models of the growing season duration for early corn

hybrids has allowed to determine that the sums of effective temperatures (≥+10°C) in May, June-August and September under correlation coefficients at the level of r = -0.62 and r = -0.51, r = 0.59 and r = 0.39, respectively, have the highest effect. In addition, the amount of precipitation significantly affected the duration of the growing season and the correlation coefficient was r = -0.44, and the effect of HTC was at the level of r = -0.34. In mid-early hybrids, by the sum of effective temperatures (≥+10 °C) in May and June under r = -0.46 and r = -0.28, respectively, as well as the sum of effective temperatures (≥ +10 °C) in August under r = 0.18 had a significant impact. As for mid corn hybrids, the duration of the growing season was determined by the sum of effective temperatures (≥+10 °C) in May, June and July under r = -0.37, r = -0.34 and r = -0.28, and the sum of effective temperatures (≥+10 °C) in August under r = 0.18. There was also observed the influence of the total sum of effective temperatures (≥+10°C) during the growing season with correlation coefficient of r = -0.51.

According to the results of research of mathematical models of the influence of weather conditions on the formation of phenotypic productivity of corn hybrids of different maturity groups, both general biological principles and group differences of the trait formation have been established. Thus, the analysis of the differences between the groups of early and medium-early corn hybrids reveals that their growth and development are generally affected to a relative extent by the sum of effective temperatures, amount of precipitation and HTC. In fact, the maturity groups studied differ insufficiently, and the main differences are observed only in the variability of the traits studied or the closeness of their relationship with each other. However, mid hybrids respond to environmental factors somewhat differently, which allows to develop the elements of adaptive cultivation technology for each maturity group.

Therefore, it can be concluded that taking into account the dependence of the manifestation of economically valuable traits in maize hybrids will effectively select maize hybrids with the necessary parameters, in this case for the production of alternative energy sources and create adaptive elements for their cultivation.

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