

## Growth and Development of Sweet Corn Plants in the Agro-Ecological Conditions of the Western Region of Ukraine

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### ABSTRACT

The results of research on the influence of growing technology and its individual elements on the growth, development and photosynthetic activity of corn plants hybrid Moreland F<sub>1</sub> under conditions of Western region of Ukraine are presented. The purpose of the research was to determine influence of cultivation technology elements on the formation and efficiency of assimilation apparatus of sweet corn plants. Research was conducted during 2019–2021 on sod–podzolic soil using field, calculation–weighting, and mathematical–statistical methods. Dynamics peculiarities of individual leaf surface area of the plant and agrocenosis of corn as a whole by the stages of crop development have been determined. Based on the results of statistical and correlation analyses, dependences between main indices of photosynthetic activity and corn yielding capacity, as well as those that change the most under influence of agrotechnology elements, were determined. Reaction of the crop on the change in intensity level of cultivation technology has been established, which is manifested through the functional response of individual photosynthetic plant system and the crop as a whole and is expressed in strengthening of their assimilation activity. Optimal limits of biometric indices of photosynthetic activity of sweet corn plants in crops when being reached, a productive grain yield is formed, have been presented.

**Keywords:** corn, assimilation surface area, leaf index of crops, photosynthetic potential, agrocenoses, mineral fertilizers, agrotechnology, soils.

### INTRODUCTION

Sweet corn is a promising vegetable crop with high economic efficiency. Its main advantages: high nutritional value; suitability for use in fresh, frozen, canned form; vegetative mass of plants is high-quality green fodder and a valuable component of silage; high profitability of production; high demand not only in domestic market, but also in foreign market; the prospect of import substitution. Therefore, sweet corn, as a crop capable to produce high and high-quality crops on reclaimed lands of soil-ecological zone of the

Western region of Ukraine, deserves careful attention [Hryhoriv et al., 2020].

In the world for the period of 2010–2015, corn for consumption in milk–wax maturity was grown on an area of 1.077 million hectares, 0.6 million hectares of which were sweet corn. Every fourth hectare under food corn is American. Almost every second ear of sweet corn comes from USA (45.98% of global yield). As a whole, the area under corn for food has increased by 157% since 1961. The largest of them are in the USA (280200 ha), Hungary (30900 ha), Canada (29700 ha), France (29900 ha), Japan (28900 ha) [Babych & Poberezhna, 2000].

Today, the average annual consumption of sweet corn per person in Ukraine is 3.7–4.3 kg. According to recommendations of Nutrition Institute of the Academy of Medical Sciences of Ukraine, an adult should consume 3.7 kg of sweet corn per year (Konoplia & Evtushenko, 1997; Bezuhlyi & Prusiazhniak, 2012; Zynchenko, 2013).

Currently, sweet corn in Ukraine, unfortunately, is not grown on an industrial scale. Crop production is fulfilled mainly by farms on small areas of 1.5–5 ha [Karelson, 2011; Karbivska et al., 2022], sometimes up to 50 ha. According to the data of the regional statistics department of Kherson region, in 2015, the area under sweet corn amounted to 200–250 hectares. One of the important prerequisites for increasing sown area and the mass implementation of this valuable and economically profitable (production profitability level of 150–400%) crop into production requires a comprehensive study and development of modern energy-saving cultivation technology [Kiver et al., 1999; Kwabiha, 2004; Oplanic et al., 2008; Hryhoriv et al., 2021].

Today, in connection with persistent trends of climate change in the direction of warming and increasing aridity, the main zone of corn grain cultivation is the Forest Steppe, and the highest yields are formed in Polissia zone, where 50 years ago it was an atypical crop. That is why development and improvement of zonal technologies for growing corn must be directed to the formation of optimal morphostructure, stress-resistant agrocenoses with high intensity of photosynthetic activity, which will maximally use agroclimatic and production resources [Kaminskyi et al., 2017].

It should be remembered that modern technologies of growing agricultural crops are based on the theory of crop formation as a photosynthetic system and are developed taking into account biological features, in particular the type of plant photosynthesis [Zaika, 1987; Saiko, 1994; Tsyuk et al., 2022]. Due to belonging to C4-type crops, corn absorbs carbon dioxide and uses solar radiation for the formation of sowing dry matter much more efficiently than C3-type crops [Shpaar et al., 2011]. This leads to a significantly higher potential individual productivity of corn plants compared to other cereals, for realization of which optimal supply of life factors – light, heat, water and nutrients – is required in economic crop [Chekalin et al., 2008; Karpenko et al., 2022].

The formation of optimal corn agrocenoses in terms of density ensures adequacy of

photosynthesis reaction due to creation of an appropriate microclimate in crops and sufficient lighting. The results of scientific research established that increasing density of corn hybrids of different maturity in the forest–steppe conditions from 80000 to 100000 units ha<sup>-1</sup> contributes to increase of the leaf surface area by 5–10%, positively affects productivity of photosynthesis and accumulation of dry matter [Kniaziuk & Lypovyi, 2016]. In the combined sowing of corn and sugar sorghum, increase in sowing norm of the components and optimization of plant nutrition area lead to improvement in their development and an increase in the yield of green mass [Hrabovskiy et al., 2018; Tanchyk et al., 2021].

Usage of various bacterial preparations, physiologically active substances and anti-stressors that activate mechanisms of immunity, stress resistance and adaptability is an important reserve of resource preservation in corn growing technology. Their use in cultivation technology allows directly and indirectly to influence formation of crops with optimal morphological and functional indicators [Chekalin et al., 2008; Mazur & Shevchenko, 2018].

So, research conducted in Western region of Ukraine convincingly proved the need to create corn agrocenoses optimal in terms of biometric parameters to increase intensity of their photosynthetic activity. Perspective of integrated management of structural and functional state of crops to increase crop yielding capacity due to optimization of cultivation technology elements is experimentally substantiated.

## MATERIAL AND METHODS

Field research was conducted during 2019–2021 on the basis of dendrological park “Friendship named after Zinovii Pavlyk” of Vasyl Stefanyk Precarpathian National University, GPS reference: latitude 58056’65’, longitude – 34041’55”.

The soils of experimental plot are sod, deep podzolic clayed, with a mechanical composition of coarse-grained heavy clay, which have a thick humus horizon of 75 cm and are characterized by the following indices: acidity, pH – 5.3, humus content (%) – 2.8, soil availability (mg kg<sup>-1</sup>): nitrogen – 78, phosphorus – 112.0, potassium – 137.0. Area of sowing plot is 50 m<sup>2</sup>, accounting area – 25 m<sup>2</sup>. Repetition in the experiment – four times. Placement of the variants is systematic in 2 layers.

Cultivation technology is generally accepted for the study region. Sowing was carried out according to the scheme of experiment. Hybrid Moreland F<sub>1</sub> was used for sowing. The topics of research included studying of such factors as: Factor A – nutrition background: control (N<sub>0</sub>P<sub>0</sub>K<sub>0</sub>); N<sub>90</sub>P<sub>90</sub>K<sub>90</sub>; N<sub>135</sub>P<sub>90</sub>K<sub>125</sub>+N<sub>60</sub>+N<sub>30</sub>. Factor B – thickening of plants, thousand ha<sup>-1</sup>: 60; 70; 80.

It should be noted that weather conditions of the Western region are formed under influence of three main factors of geographical origin, circulation of air masses and bedding surface. An important climate-forming factor of this region is the Carpathians, which affect distribution of air currents near the earth's surface. Precarpathians is a moderately warm and humid area.

To achieve the goal, general scientific and special research methods were used: field – to establish relationship of the object with biotic and abiotic factors; calculation – to determine the area of leaf surface by multiplying the largest width of the leaf by its length and by a factor of 0.75, photosynthetic potential of sowing as the sum of leaves areas for a certain period of time (according Nychiporovich); calculating and weighing – to determine vegetative mass of plants and corn sowing. Mathematical and statistical methods were used to establish reliability of the obtained data and to identify mathematical dependencies [Nichiporovich, 1977].

## RESULTS AND DISCUSSION

Recently, significant changes have been taking place in the Earth's biosphere, the general trend of which, according to scientific community, is global warming. Processes of a planetary scale cannot fail to influence the latter in systems of a lower order: continental, regional, local. The global change in climatic conditions, in turn, leads to a change in the climate of certain regions of the planet, which, of course, is of great importance for agricultural science. First of all, the species and varietal composition of cultivated crops undergo significant changes, new species and varieties of plants require agrotechnologies that are able to ensure efficient, stable production of plant products under new conditions. In addition, scientific and technical progress does not stand still, which requires agrarians to constantly improve existing technologies for growing crops.

It is known that in the process of vegetation, corn plants are formed with different indices of individual leaf surface area, which in turn has an impact on the total leaf surface area of the agroecosystem, as well as on its functional activity and work efficiency. An important prerequisite for obtaining high yields is the most effective consumption of photosynthetically active radiation by crops, which is impossible without a developed assimilation apparatus [Nuliaev, 1963; Rieznik et. al., 2021]. It should have an optimal area and provide the best work in terms of intensity and quality in all phases of plant growth and development [Nichiporovich, 1977]. Optimal area formation of leaf apparatus by crops depends on agroclimatic and technological conditions of growing agricultural crops, in particular, on soil cultivation, mineral fertilizers, plant thickening, etc. The study of cultivation technology influence on the formation, development and productivity of photosynthesis is a necessary prerequisite for intelligent management of yield potential of cultivated plants.

The results of conducted research, namely measurement of leaf surface area per sweet corn plant, indicate that thickening of plants from 60 to 80 thousand ha<sup>-1</sup> leads to a significant decrease. However, with a greater density of plant stands, the area of crop's assimilation apparatus per 1 ha (leaf index) increases. This indicates that degree of decrease in the area of assimilation surface per plant with thickening is less than increase in its total area per 1 ha. Application of mineral fertilizers leads to a significant increase in the area of leaf apparatus. Improvement of nutrition regime of the soil is the most influential factor in the formation of strong sweet corn plants with a well-developed leaf apparatus.

Results of measuring leaf surface area of sweet corn plants according to main vegetation phases showed its rapid increase in the period from the phase of 3–5 leaves until blossoming (by 2292–3041 cm<sup>2</sup> according to the experiment variants). Tempo of area growth of crop assimilation apparatus from blossoming phase to beginning of milk-wax ripening of grain increases from 994–1193 cm<sup>2</sup> (Table 1). Thus, taking into account above-mentioned peculiarities, main attention should be paid to the formation of strong and potentially high-yielding sweet corn plants at early stages of growth and development of the crop, as it is during this period an intensive increase in assimilation surface is noted.

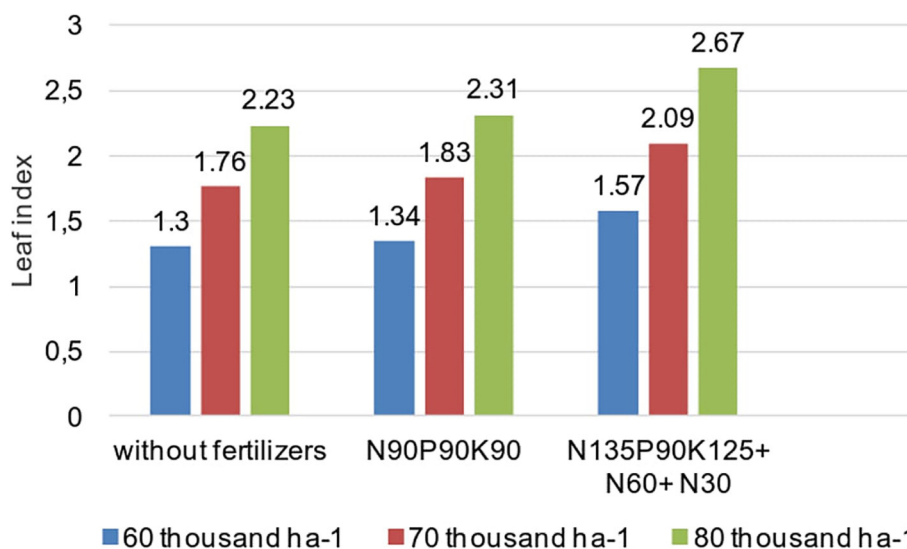
**Table 1.** Leaf surface area of one sweet corn plant, cm<sup>2</sup>, average for 2019–2021

Nutrition background	Thickening of plants, thousand ha <sup>-1</sup>	Phenological phase		
		3–5 leaves	Blossoming	Beginning of MWR of grain
Control (without fertilizers)	60	68	2433	3585
	70	65	2342	3465
	80	63	2292	3286
N <sub>90</sub> P <sub>90</sub> K <sub>90</sub>	60	76	2617	3677
	70	74	2579	3588
	80	71	2477	3356
N <sub>135</sub> P <sub>90</sub> K <sub>125</sub> +N <sub>60</sub> +N <sub>30</sub>	60	92	3041	4234
	70	88	2934	4135
	80	76	2798	3995
LSD <sub>05</sub> , cm <sup>2</sup>	A	2.7	13.3	22.1
	B	2.1	11.5	17.4
	AB	5.9	32.7	46.1

An important evaluation index of cultivation technology according to its effectiveness in providing optimal conditions for growth, plant development and agrocenosis formation with high potential productivity and maximum full use of solar energy is leaf index, which shows how many m<sup>2</sup> of assimilation apparatus per 1 m<sup>2</sup> of sown area. It is believed that maximum net productivity of agrophytocenosis of most agricultural plants can be achieved with a leaf surface index of about 4–5. It should be taken into account that leaf index value depends on a number of biotic and abiotic factors, biological and morphological features of plants, peculiarities of agricultural technology, etc. In our experiments, this index practically did not depend on the area of one plant leaf surface (correlation

coefficient R was 0.15, determination coefficient was 0.025), however, it was strongly influenced by density of crops (correlation coefficient R was 0.84, determination coefficient – 0.70). The results of our research determined that leaf index increases with thickening of plants and an increase in a dose of mineral fertilizers.

Thus, it was determined that minimum value of this index on the variant without fertilizers and plant thickening of 60 thousand ha<sup>-1</sup> was 1.30, and maximum value was 2.67 on the variant with application of mineral fertilizers at a dose of N<sub>135</sub>P<sub>90</sub>K<sub>125</sub>+N<sub>60</sub>+N<sub>30</sub> and plant thickening of 80 thousand ha<sup>-1</sup>. It should be noted that fluctuation amplitude of leaf index of sweet corn crops according to the variants of the experiment was 2.4 (Fig. 1).



**Figure 1.** Leaf index of sweet corn crops at the beginning of milk-wax ripeness of grain, average for 2019–2021

**Table 2.** Interphase photosynthetic potential of sweet corn crops, million m<sup>2</sup> ha<sup>-1</sup> per day, average for 2019–2021

Nutrition background	Thickening of plants, thousand ha <sup>-1</sup>	Inter-phasal period		
		3–5 leaves – blossoming	Blossoming – beginning of MWR of grain	3–5 leaves – beginning of MWR of grain
Control (without fertilizers)	60	0.15	0.35	0.46
	70	0.19	0.45	0.57
	80	0.24	0.54	0.70
N <sub>90</sub> P <sub>90</sub> K <sub>90</sub>	60	0.17	0.39	0.47
	70	0.23	0.51	0.65
	80	0.29	0.61	0.76
N <sub>135</sub> P <sub>90</sub> K <sub>125</sub> +N <sub>60</sub> +N <sub>30</sub>	60	0.22	0.46	0.61
	70	0.28	0.59	0.79
	80	0.35	0.71	0.95

Calculation of interphase photosynthetic potential of sweet corn crops for main periods of its growth and development confirmed aforementioned regularities of assimilation apparatus formation of the crop. Maximum photosynthetic potential was observed in crops on the variants with application of mineral fertilizers at a dose of N<sub>135</sub>P<sub>90</sub>K<sub>125</sub>+N<sub>60</sub>+N<sub>30</sub> and plant thickening of 80 thousand ha<sup>-1</sup>, and minimum – on unfertilized areas with plant thickening of 60 thousand ha<sup>-1</sup>.

Thus, it was found that increasing the dose of mineral fertilizers from 0 to 225 kg ha<sup>-1</sup> increased photosynthetic potential of crops by 55.7% on average during interphase periods. Whereas, according to the phases of growth and development of the crop, a gradual increase in photosynthetic potential due to increase in the area of leaf apparatus of the crop was noted. Interphase photosynthetic potential of sweet corn crops in the period from 3–5 leaves to the beginning of milk-wax ripeness of grain was within limits from 0.46 to 0.95 million m<sup>2</sup> ha<sup>-1</sup> per day (Table 2).

It should be noted that our research results are confirmed by the previous work of Lindsey and Thomison, who claim that hybrid ripeness is a key factor influencing the ratio of yielding capacity and density of corn crops [Lindsey & Thomison, 2016]. According to their research, yielding capacity potential of short-period hybrids was similar to full-period hybrids due to efficient agrotechnology, and plant density for maximum yield was greater for short-period hybrids than full-period ones [Sarlangue et al., 2007; Solomon et al., 2017].

Thus, separately, all above biometric indices cannot be used as direct markers of crop productivity. Their value makes it possible to

assess condition of crops, degree of agrotechnology intensity etc., but does not make it possible to accurately predict the crop yielding capacity, which depends not only on amount of absorbed photosynthetically active radiation per unit of sown area, but also on other abiotic, biotic and agrotechnological factors. Our observations are confirmed by the works of Kolisnyk and Didur, who say that technological methods of cultivation have an extremely large influence on realization of yielding capacity potential of modern corn [Kolisnyk et al., 2019; Kolisnyk et al., 2020; Didur et al., 2019].

## CONCLUSIONS

The perspective has been determined, and possibility of increasing efficiency of photosynthetic activity and production process of corn plants thanks to creation of agrocenoses with optimal functional characteristics, which is achieved by the use of improved cultivation technologies, have been experimentally confirmed.

It has been found that under conditions of the Western region of Ukraine, when growing sweet corn for grain using the most effective technologies that provide a larger leaf surface area per plant, sweet corn forms with application of mineral fertilizers at a dose of N<sub>135</sub>P<sub>90</sub>K<sub>125</sub>+N<sub>60</sub>+N<sub>30</sub> and plant thickening of 60 thousand ha<sup>-1</sup> (at the beginning of milk-wax ripeness of grain 4234 cm<sup>2</sup>). The maximum leaf index (2.67) and photosynthetic potential (0.95 million m<sup>2</sup> ha<sup>-1</sup> per day) of the crops are formed when applying mineral fertilizers in a dose of N<sub>135</sub>P<sub>90</sub>K<sub>125</sub>+N<sub>60</sub>+N<sub>30</sub> and plant thickening of 80 thousand ha<sup>-1</sup>.

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