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RESEARCH ARTICLE

Effect of the elements of corn cultivation technology on bioethanol production under conditions of the right-bank forest-steppe of Ukraine

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The paper presents the results of a three-year research on the technology of corn cultivation and efficiency of starch utilization as bio-feedstock for bioethanol production in Ukraine. Peculiarities of carbohydrate accumulation in corn hybrids depending on the fraction size, seeding depth and conditions of cultivation are determined. The effect of seed fraction size (small, medium and large), seeding depth (4, 7 and 11 cm) on the yield, starch content and output, approximate bioethanol output in corn hybrids of three maturity groups (early- 'DKC 2960' and 'DKC 2971', mid-early- 'DKC 3472', 'DKC 3795', and mid- 'DK 315' and 'DKC 4082' originated by the company DEKALB Monsanto Ukraine) is analyzed. The influence of environmental conditions on the studied characteristics and indicators is revealed. Dependence of productivity, starch content and bioethanol output on the seeding depth and seed fraction size is disclosed. There has been observed the growth of genetic control of these indicators depending on the specific hybrid, compared to the investigated technology elements. Application of large linear-size seeds and the optimum seeding depth of 4-7 cm provide an opportunity to increase the yield, starch content and bioethanol output.
Key words: Bioethanol; bio-feedstock; hybrid; seeding depth; corn; yield; seed fraction

Introduction

Possession of domestic fuel is an urgent need for Ukraine. Dependence on the imported fuels makes Ukraine vulnerable to external factors. This problem also affects the agrarian sector as sustainable agribusiness and some farming practices depend directly on the farmers' supply with fuel and lubricants, especially nowadays, when the cost of imported fuel is constantly rising.

Therefore, a search for alternatives is a current demand. One of the ways has already been found, namely production of a domestic substitute for imported fuel products, i.e., bioethanol obtained due to processing of natural feedstock containing carbohydrates.

Energy derived from biomass is expected to be a key contributor to the future energy sector, which, together with other renewables, can help supply energy to billions who lack it (Lin and Tanaka, 2006).

Bioethanol is a liquid biofuel produced from biomass via fermentation process. As 40% of world's energy consumption is in the form of the liquid fuels, diesel and gasoline (Tan et al., 2008), liquid biofuels are considered a natural alternative to supplement conventional oil derived fuels (Thiruvengadathan, 2017).

With global production crossing 100 billion liters in 2016 (Renewable Fuels Association), ethanol is expected to remain the most prominent and cost-effective biofuel for the foreseeable decades, with prices approaching that of gasoline (Eisentraut et al., 2011).

At present, bioethanol production is almost the only way to ensure Ukraine's energy independence since the domestic agro-industrial complex is able to increase bioethanol production in the short terms. Potential opportunities for this approach are enormous, since the processing of just 10 million tons of corn let Ukraine produce at least 4 million tons of bioethanol.

Moreover, when Ukraine has joined the Energy Community Treaty, our state has got obligations on the implementation of EU Directives 2009/28/EC on the introduction of biofuels, which requires to increase bioethanol proportion in motor fuel up to 10% by 2020 (State Energy Efficiency and Energy Saving Agency of Ukraine).

The issues of providing favorable conditions for biofuel producers and selecting the most efficient agricultural feedstock for bioethanol production in Ukraine are of controversial nature that makes this study relevant.

Theoretical and practical aspects of the efficiency and expediency of biofuel production and consumption have been studied by such researchers as V. Dubrovin, O. Zozulia, H. Kaletnik, S. Oliinichuk, Gal Hochman, David Zilberman, GianCarlo Moschini, Harvey Lapan, and Hyunseok Kim, Christina Korting, Harry de Gorter, and David Just, Christina Korting, David R. Just, Yanbing Wang, Michael S. Delgado, Benjamin Gramig, Juan Sesmero, Matthew S. Clancy, GianCarlo Moschini, Gabriel E. Lade, C.-Y. Cynthia Lin Lawell, Aaron Smith and others. However, all these studies are rather general and examine the concepts of eco-friendly production at the national and, to a greater extent, international, global levels. At the same time, insufficient attention has been paid to investigation of the opportunities of starch utilization for bioethanol output considering specifics of genetic features of corn hybrids and such elements of the cropping system as seed fraction and seeding depth.

High starch contents in cereal grains make them good feed stocks for conversion into biofuels and other bio-based products. Ethanol is the only bio fuel that has been produced commercially from these feed stocks in large quantities. The amount of grain utilized neither for food, nor for feed purposes has grown in recent years. The production of ethanol from corn for use as a transportation fuel is mature technology. It was first introduced in the United States in the early 1900s. Today, most fuel ethanol is produced from corn either by the dry grind (67%) or the wet mill (33%) process (Gawande and Patil, 2014).

Today's global “bioethanol boom” has caused an increase in demand for corn as the most effective feedstock for production of ethanol, i.e., dehydrated alcohol. High carbohydrate content (68-85%) in corn grain provides favorable conditions for bioethanol production, which can be used as a component of the mixture with gasoline (optimal proportion of these fuel materials is 85:15) to increase octane number and oxygen content, which improves conditions for the mixture combustion (Yianosh, 2012; Polishkevich, 2011).

Utilization of bioethanol will save the environment and effectively control the global warming mainly due to refusal from oil and transition to new renewable fuels (Rybalka et al., 2013).

One ton of corn grain provides 325-470 l of ethanol, whereas barley provides 240-330 liters, rye-280-357 liters, wheat-375-445 liters (Yianosh, 2012; Kaletnik, 2015; Kamenshchuk, 2012; Kamenshchuk, 2013; Hoysaliuk, 2015), triticale-428 liters, wheat-445 liters, sorice-464 liters. Although sorice has a higher starch content, it is harder to hydrolyze it, therefore bioethanol output from corn is higher (Dudka, 2012). To produce 1.0 t of bioethanol, 0.64 hectares of wheat or 0.47 hectares of corn are required (Yianosh, 2012)

Bioethanol output depends primarily on starch content in grain, which in its turn is determined by maturity group, subtype of hybrid and cropping system. Thus, early hybrids in the Forest-Steppe zone of Ukraine do not have high grain yield and starch output, although some of them have high starch content. Mid and mid-early hybrids have the highest starch content as they are a tooth-type subspecies that contain more starch in grain (Huriev and Levandovsky, 2010; Zahinaylo et al., 2012). Thus, evaluation of suitability of modern corn hybrids for bioethanol production and the elements of cultivation technology in order to increase starch content is of great relevance.

The purpose of paper is to develop guidelines to improve Ukraine's energy security, identify the peculiarities of carbohydrate accumulation in corn hybrids depending on the elements of cultivation technology, which will contribute to the growth of bioethanol production and provide additional opportunities for agriculture.

Material and methodology

The research was conducted at Vinnytsia National Agrarian University and the state enterprise “Experimental Farm “Kordelivske” of the Institute of Potato Studies of the National Academy of Agrarian Sciences of Ukraine, village Kordelivka, Kalynivka district, Vinnytsia oblast in 2014-2016. According to the zonal location, the farm is situated in the central part of the right-bank Forest-Steppe of Ukraine.

The experiments were aimed to determine corn productivity, starch content, bioethanol output and another economic and biological features depending on the fraction size (S-small, M-medium, L-large seed) and seeding depths (4, 7 and 11 cm) of hybrid seeds of the early group DKS 2960, DKS 2971, mid-early group DKS 3472 and DKS 3795, and mid group DKS 4082 and DK 315 originated by MONSANTO.

Soils were black deep loess mid-loams. Humus content (according to Tiurin) in the arable layer was 4.6%. Soil pH was 5.7 (almost neutral); weight average: hydrolytic acidity 40 mg equivalents per 1 kg of soil; the amount of absorbed bases-158 mg equivalents per 1 kg of soil (according to Kappen-Hilkovits); the degree of saturation with the bases-82.3%. Agro-physical properties: soil density-1.2 g/cm^3. The soils contained easily hydrolyzed nitrogen (according to Cornfield) of 106 mg per 1 kg of soil, labile phosphorus and exchangeable potassium (according to Chyrikov) of 186 and 160 mg per 1 kg of soil, respectively.

Soil and climatic conditions were characterized by certain diversity, among which it is necessary to note dry conditions of 2015 with temperature parameters that exceeded 42°C. In 2014 and 2016, climatic conditions were the most favorable for the growth and development of corn plants.

Seeding was carried out by a seeder SUPN-8 updated according to the rate of 75 thousand seeds per hectare. Replication-3-4 times. Site location was conducted by the method of randomized blocks. The cropping area was 25 m^2, reported area was 10.5 m^2.

Determination of starch content was carried out using the polarimeter A (manufactured by CARL ZEISSJENA, Germany) with the accuracy of 0.1% in accordance with the requirements of State Standard 46.045:2003 “Grain. Methods of relative starch determination” of July 25, 2003, N250. The polarimetric method is based on the ability of carbohydrate solutions (dissolved starch, dextrins, oligosaccharides, sugars) to rotate the area of polarization of polarized light. In order to determine relative starch of grain by polarimetric method, starch and other carbohydrates of grain were transferred to the solution by hydrolysis under certain conditions with subsequent determination of the angle of rotation of the area of polarization of polarized light with this solution using a polarimeter.

Starch content was calculated according to the formula , where x is starch content in percent, α is the indicator of sugarmeter, %; K-Evers's coefficient (=1,898) (Wu et al., 2006; AACCI Method 76-13.01 Total Starch Assay Procedure, 2000).
Bioethanol yield from the feedstock is usually calculated as ethanol output. Ethanol output is its amount obtained from the tone of the native carbohydrates in terms of starch. Theoretical output is calculated by the equation of alcohol fermentation, i.e., $C_6H_{12}O_6=2C_2H_5OH+2CO_2$.
Under relative density of ethanol d420=0,78927 its theoretical output is 54.79 liters (Priadkina, 2013).

Results of research and their discussion

Analysis of data in Table 1 shows that grain yield in corn hybrids significantly depended on the hybrid maturity group (factor A). On the average for three years, the yields of mid-early and mid hybrids increased significantly, by 0.95 and 1.88 t/ha, respectively, compared with early hybrids (LSD05maturity group=0,388 t/ha). Thus, grain yield of early hybrids was 8.12 t/ha, mid-early hybrids- 9.07 t/ha and mid hybrids-10.00 t/ha. Consequently, the tendency towards prolongation of the growing season leads to higher grain yield.
Grain yield also depended on genetic features of the hybrid (factor B). Grain yield of hybrid DKS 2960, on the average for three years (LSD 05 hybrid=0,347 t/ha), was 8.19 t/ha, DKS 2971-8.05 t/ha, DKS 3472-9.41 t/ha, DKS 3795-8.72 t/ha, DK 315-9.96 t/ha, and DKS 4082-10.03 t/ha. Therefore, a significant difference in the productivity of the studied hybrids is observed even within one maturity group.
In order to estimate starch output per unit of area when applying foliar nutrition, we present data on hybrid productivity over the research period (Table 1).

Table 1. Yield of corn hybrids depending on the seeding depth and seed size, t/ha (over 2014-2016).

Maturity group (A)	Hybrid name (B)	Seed fraction (C)	Seeding depth (D)	Year			Average ±Sr
				2014	2015	2016	
Early hybrids	DKC 2960	S* (187 g)	4 cm	7.61	7.14	8.46	7.74 ± 0.67
			7 cm	7.92	7.29	7.95	7.72 ± 0.37
			11 cm	7.28	7.08	7.24	7.20 ± 0.11
		M** (238 g)	4 cm	9.35	7.21	8.94	8.50 ± 1.14
			7 cm	9.21	7.7	8.59	8.50 ± 0.76
			11 cm	8.83	7.83	8.46	8.37 ± 0.51
		L*** (277 g)	4 cm	9.15	7.23	9.28	8.55 ± 1.15
			7 cm	8.79	7.58	9.01	8.46 ± 0.77
			11 cm	8.86	7.88	9.27	8.67 ± 0.71
	DKC 2971	S* (194 g)	4 cm	7.48	7.18	8.66	7.77 ± 0.78
			7 cm	7.18	7.24	8.46	7.63 ± 0.72
			11 cm	6.95	6.91	7.39	7.08 ± 0.27
		M** (256 g)	4 cm	8.2	8.05	8.64	8.30 ± 0.31
			7 cm	8.12	7.82	8.9	8.28 ± 0.56
			11 cm	8.36	7.7	8.54	8.20 ± 0.44
		L*** (279 g)	4 cm	8.62	7.85	8.93	8.47 ± 0.56
			7 cm	8.46	7.74	8.99	8.40 ± 0.63
			11 cm	8.63	7.78	8.62	8.34 ± 0.49
Mid-early hybrids	DKC 3472	S* (249 g)	4 cm	8.27	7.99	11.11	9.12 ± 1.73
			7 cm	8.4	7.91	10.43	8.91 ± 1.34
			11 cm	8.11	7.84	9.96	8.64 ± 1.15
		M** (326 g)	4 cm	9.1	9.02	11.16	9.76 ± 1.21
			7 cm	9.07	8.88	10.97	9.64 ± 1.16
			11 cm	9.16	8.96	10.89	9.67 ± 1.06
		L*** (385 g)	4 cm	9.07	8.84	11.18	9.70 ± 1.29
			7 cm	9.17	9.14	10.8	9.70 ± 0.95
			11 cm	9.2	8.75	10.78	9.58 ± 1.07
	DKC 3795	S* (166 g)	4 cm	8.27	7.76	9.08	8.37 ± 0.67
			7 cm	7.99	7.94	8.71	8.21 ± 0.43
			11 cm	7.88	7.57	8.09	7.85 ± 0.26
		M** (207 g)	4 cm	8.91	8.93	9.73	9.19 ± 0.47

			7 cm	8.93	8.24	8.9	8.69 ± 0.39
			11 cm	8.95	8.51	8.94	8.80 ± 0.25
		L*** (287 g)	4 cm	9.06	8.87	9.94	9.29 ± 0.57
			7 cm	9.09	8.08	9.64	8.94 ± 0.79
			11 cm	9.05	8.55	9.76	9.12 ± 0.61
Mid hybrids	DK 315	S* (223 g)	4 cm	9.1	8.91	10.58	9.53 ± 0.91
			7 cm	9.23	8.86	10.28	9.46 ± 0.74
			11 cm	9.04	8.39	9.89	9.11 ± 0.75
		M** (294 g)	4 cm	9.8	9.51	10.78	10.03 ± 0.67
			7 cm	10.13	9.61	10.86	10.20 ± 0.63
			11 cm	10.28	9.51	10.8	10.20 ± 0.65
		L*** (327 g)	4 cm	9.99	9.91	11.02	10.31 ± 0.62
			7 cm	10.57	9.91	11.08	10.52 ± 0.59
			11 cm	10.02	9.73	11.18	10.31 ± 0.77
	DKC 4082	S* (172 g)	4 cm	9.06	9.21	10.2	9.49 ± 0.62
			7 cm	8.9	9.06	10.09	9.35 ± 0.65
			11 cm	8.86	8.57	9.72	9.05 ± 0.60
		M** (227 g)	4 cm	9.41	9.52	11.24	10.06 ± 1.03
			7 cm	10.35	9.75	11.59	10.56 ± 0.94
			11 cm	10.73	9,60	11.52	10.62 ± 0.97
		L*** (278 g)	4 cm	9.76	9.61	10.96	10.11 ± 0.74
			7 cm	10.33	9.68	11.48	10.50 ± 0.91
			11 cm	10.49	9.66	11.43	10.53 ± 0.89

LSD05, t/ha Factor A– 0.388; Factor B-0.347; Factor C-0.734; Factor D-0.107.
-small seed fraction; **-medium seed fraction; *-large seed fraction.*

Analysis of the effect of the seed fraction size (factor C) on the grain yield shows that sowing of medium and large fractions of hybrids of all maturity groups resulted in reliably higher yields compared with sowing of smalls seeds (LSD05 seed fraction = 0,734 t/ha). Thus, when sowing small seed fraction, the yield of the investigated hybrids, on the average for three years, ranged within 7.49-9.36 t/ha, medium seed-8.26-10.41 t/ha, large seed-8.4-10.38 t/ha. Therefore, when sowing medium and large seed fraction, yield increase was 0.91-1.05 t/ha, compared with the use of small seed fraction.
The seeding depth (factor D) also affected the productivity of the studied hybrids. Thus, when seeding at the depth of 4 cm, plant productivity of the studied corn hybrids, on the average for three years of research, amounted to 9.128 t/ha, at the depth of 7 cm-9.093 t/ha, and at the depth of 11 cm-8.961 t/ha. At the same time, when the seeding depth was 4 cm the yield ranged within 8.18-9.96 t/ha, 7 cm-8.10-10.14 t/ha, and 11 cm-7.88-10.06 t/ha.
The research results have shown a yield increase only in hybrid DKS 4082 under significant seeding depth (11 cm). In particular, when seeding at the depth of 4 cm, the yield of this hybrid, on the average for three years, was 9.89 t/ha, at the depth of 7 cm-10.14 t/ha, and at the depth of 11 cm-10.06 t/ha.
Consequently, the yield of the hybrids studied was determined by the hybrid maturity group, genetic features and elements of the cropping system such as seed fraction and seeding depth. Besides, grain yield significantly depended on the climatic conditions of the year, in particular, in 2015 due to the stressful conditions of moisture supply and high positive temperatures (> 42 ° C), there was observed a general decline in yields compared with 2014 and 2016.
Starch content in grain is the main indicator that determines if a hybrid can be used for bioethanol production. Hybrids that have high starch content in grain can be recommended to be grown for bioethanol.
A series of field studies have been conducted to study the effect of the seeding depth and seed fraction size on the starch content.
It is clear that the seed size directly determines the size of both the embryo and the endosperm in which starch is the main storage substance. In this regard, it is important how endosperm formation will change while changing data of the elements of crop cultivation technology.
Describing the dynamics of starch content over the years of research, it is necessary to note the decline in starch amount in 2015. Thus, on the average, starch content in the studied hybrids was 75.46% in 2014, 72.17% in 2015, and 74.58% in 2016. This is due to the fact that that year had the least uniform moisture supply with a long dry period, which ultimately affected starch accumulation.
This dependence is confirmed by other researches. In particular, Pavlov's (1967) research indicates that the rise of the average annual temperature and reduction of the annual precipitation increases protein content in grain, while starch content decreases. Temperature increase during the growing season often results in the protein increase in cereal grain, while starch and protein content are antagonistic indicators. Analysis of starch content in corn grain reveals its change depending on the

hybrid maturity group (factor A). The highest starch content of 75.40%, on the average for three years, was observed in the group of mid hybrids; it significantly (LSD05 maturity group = 1,99%) differed by its content from the group of early hybrids (72.33%) and mid-early hybrids (74.48%).

The highest starch content was recorded in the group of mid hybrids, where starch content in hybrid DK 315, on the average for three years, was 74.46%, 74.72% and 74.32% when sowing small seed, 75.7%, 76.16 and 75.69% when sowing medium seed, and 75.53%, 75.66 and 75.36% when sowing large seed; in hybrid DKS 4082, starch content was 73.8%, 74 , 62 and 74.36% when sowing small seed, 76.13%, 76.78 and 76.46% when sowing medium seed, and 74.93%, 76.64 and 75.92% when sowing large seed, under the seeding depth of 4, 7 and 11 cm, respectively.

The effect of the fraction size and seeding depth of corn hybrids on the starch content is shown in Table 2.

Table 2. Starch content in corn seed depending on the fraction size and seeding depth, %

Maturity group (A)	Hybrid name (B)	Seed fraction (C)	Seeding depth (D)	Year 2014	2015	2016	Average ± Sr
Early hybrids	DKC 2960	S* (187 g)	4 cm	71.98	70.25	72.8	71.68 ± 1.30
			7 cm	72.86	70.19	72.96	72.00 ± 1.57
			11 cm	73.46	69.03	73.12	71.87 ± 2.47
		M** (238 g)	4 cm	73.45	71.17	73.5	72.71 ± 1.33
			7 cm	74.52	70.89	74.64	73.35 ± 2.13
			11 cm	74.96	69.18	75.06	73.07 ± 3.37
		L*** (277 g)	4 cm	72.99	70.76	73.2	72.32 ± 1.35
			7 cm	74.65	70.47	73.5	72.87 ± 2.16
			11 cm	74.92	70.44	73.96	73.11 ± 2.36
	DKC 2971	S* (194 g)	4 cm	71.7	71.29	71.93	71.64 ± 0.32
			7 cm	71.99	70.36	72.86	71.74 ± 1.27
			11 cm	72.11	70.22	72.06	71.46 ± 1.08
		M** (256 g)	4 cm	72.43	71.88	73.1	72.47 ± 0.61
			7 cm	72.53	71.12	73.01	72.22 ± 0.98
			11 cm	72.93	70.3	74.39	72.54 ± 2.07
		L*** (279 g)	4 cm	72	72.35	72.02	72.12 ± 0.20
			7 cm	72.57	71.46	73.79	72.61 ± 1.17
			11 cm	72.94	69.93	73.5	72.12 ± 1.92
Mid-early hybrids	DKC 3472	S* (249 g)	4 cm	74.46	72.66	73.87	73.66 ± 0.92
			7 cm	74.86	72.45	74.81	74.04 ± 1.38
			11 cm	75.28	72.39	75.1	74.26 ± 1.62
		M** (326 g)	4 cm	75.74	73.54	74.52	74.60 ± 1.10
			7 cm	76.05	72.5	76.85	75.13 ± 2.32
			11 cm	76.63	72.03	76.14	74.93 ± 2.53
		L*** (385 g)	4 cm	74.9	72.03	74.19	73.71 ± 1.49
			7 cm	75.88	71.62	75.63	74.38 ± 2.39
			11 cm	75.96	70.35	75.54	73.95 ± 3.12
	DKC 3795	S* (166 g)	4 cm	74.78	73.4	72.78	73.65 ± 1.02
			7 cm	74.42	72.85	74.55	73.94 ± 0.95
			11 cm	74.82	72.04	74	73.62 ± 1.43
		M** (207 g)	4 cm	75.36	74.12	73.72	74.40 ± 0.86
			7 cm	76.09	73.26	75.42	74.92 ± 1.48
			11 cm	77.67	72.15	76.27	75.36 ± 2.87
		L*** (287 g)	4 cm	76.18	75.89	72.49	74.85 ± 2.05
			7 cm	77.89	73.09	76.21	75.73 ± 2.44
			11 cm	77.96	72.78	75.74	75.49 ± 2.60
Mid hybridsm	DK 315	S* (223 g)	4 cm	76.54	71.89	74.95	74.46 ± 2.36
			7 cm	77.13	71.63	75.4	74.72 ± 2.81
			11 cm	77.99	70.26	74.71	74.32 ± 3.88

	M** (294 g)	4 cm	77.93	73.8	75.38	75.70 ± 2.08
		7 cm	78.66	72.96	76.87	76.16 ± 2.91
		11 cm	78.93	72.12	7602	75.69 ± 3.42
	L*** (327 g)	4 cm	76.64	73.87	76.08	75.53 ± 1.46
		7 cm	77.63	72.42	76.94	75.66 ± 2.83
		11 cm	78.12	72.29	75.68	75.36 ± 2.93
DKC 4082	S* (172 g)	4 cm	75.01	73.33	73.07	73.80 ± 1.05
		7 cm	77.51	72.87	73.48	74.62 ± 2.52
		11 cm	75.91	72.54	74.63	74.36 ± 1.70
	M** (227 g)	4 cm	77.02	75.21	76.17	76.13 ± 0.91
		7 cm	78.31	74.8	77.24	76.78 ± 1.80
		11 cm	78.68	73.95	76.74	76.46 ± 2.38
	L*** (278 g)	4 cm	76.44	74.12	74.22	74.93 ± 1.31
		7 cm	78.4	74.96	76.57	76.64 ± 1.72
		11 cm	78.08	73.77	75.9	75.92 ± 2.16

LSD05, t/ha Factor A– 1.99; Factor B-1.73; Factor C- 0.28; Factor D-0.22.
-small seed fraction; **-medium seed fraction; *-large seed fraction*

There was recorded an increase in starch content in later corn forms, which were represented mainly by a tooth-type subspecies.

There is data that starch content is influenced by the hybrid characteristics and the type of corn grain.

Various corn hybrids (factor B) were analyzed to determine the dependence of genetic features of the hybrid and starch content in grain. Thus, starch content in grain of different hybrids was significantly different (LSD05 hybrid = 1.73%), and on the average for three years, it was 72.55% in DKS 2960, 72.1% in DKS 2971, 74.3% in DKS 3472, 74.66% in DKS 3795, 75.29% in DK 315, and 75.52% in DKS 4082.

Starch content is significantly (LSD05 seed fraction = 0.28%) affected by the seed fraction size (factor C). Thus, when applying small seeds, starch content in grain was 73.33%, medium see-74.59%, and large seed-74.3%. When applying small seed fraction, starch content in grain, on the average for three years, ranged within 71.61-74.5%, medium seed fraction-72.41%, and large seed fraction-72.28-75.83%.

Starch content also significantly (LSD05 seeding depth = 0.22%) changed depending on the seeding depth (factor D). Thus, when seeding at the depth of 4 cm, starch content was 72.08-75.23%, 7 cm-72.19-76.02%, 11 cm-72.04-75.58%. The highest starch content in grain, on the average for three years, amounted to 74.31% when seeding at the depth of 7 cm, but when seeding at the depth of 4 cm it was 73.8%, and when seeding at the depth of 11 cm it was 74.11%.

Starch output per unit of area was also affected by the genetic features of hybrids (factor B). Thus, a significant difference (LSD05 hybrid = 0.161 t/ha) in starch output was observed within maturity groups. In particular, on the average for three years, starch output was 5.95 t/ha in DKS 2960, 5.81 t/ha in DKS 2971, 7.00 t/ha in DKS 3472, 6.51 t/ha in DKS 3795, 7.51 t/ha in DK 315, and 7.58 t/ha in DKS 4082.

Starch output per unit area also significantly (LSD05 seed fraction = 0.558 t/ha) depended on size of seed fraction (factor C). When applying a small seed fraction, starch output, on the average for three years, ranged within 5.43-6.98 t/ha, which averaged 6.21 t/ha, when applying a medium seed fraction-5.98-7.97 t/ha and 6.96, and when applying a large seed fraction-6.08-7.87 t/ha and 7.01 t/ha. Thus, the highest starch output was provided by the large seed fraction.

Seeding depth (factor D) also affected starch content in grain of the studied corn hybrids. Shallow seeding (4 cm) provided starch output, on the average for three years of research, within 5.9-7.49 t/ha, or the mean of 6.75 t/ha, seeding depth of 7 cm-5.85 -7.71 t/ha, or the mean of 6.78 t/ha, and deep seeding (11 cm)-5.68-7.62 t/ha, or the mean of 6.66 t/ha.

Data presented in Table 3 show that bioethanol output can significantly vary (LSD05 maturity group = 0.124 thousand l/ha) depending on the hybrid maturity group. Thus, approximate bioethanol output in early hybrids, on the average for three years, was 3.22 thousand l/ha, in mid-early hybrids-3.70 thousand l/ha and in mid hybrids-4.13 thousand l/ha.

In addition, there should be observed a significant impact of abiotic factors of the year on bioethanol output. Thus, in particular, approximate bioethanol output in the studied hybrids had the mean of 3.70 thousand l/ha in 2014, 3.34 thousand l/ha in 2015, and 4.01 thousand l/ha in 2016. The year of 2016 appeared to be the most favorable one by the moisture supply and temperature for this indicator.

Genetic features of the hybrid (factor B) also affected the approximate bioethanol output. Thus, bioethanol output under such starch content and yield (see Tables 1-3), on the average for three years, significantly differed in the studied hybrids (LSD05 hybrid = 0.09 thousand l/ha) and equaled 3.26 thousand l/ha in DKS 2960, 3.18 thousand l/ha in DKS 2971, 3.84 thousand l/ha in DKS 3472, 3.57 thousand l/ha in DKS 3795, 4,11 thousand l/ha in DK 315, and 4,15 thousand l/ha in DKS 4082.

Based on the values of the basic indicators for determining bioethanol output, we will assess this value depending on the seeding depth and seed fraction size (Table 3).

Table 3. Approximate bioethanol, thousand l/ha.

Maturity group (A)	Hybrid name (B)	Seed fraction (C)	Seeding depth (D)	Year			Average ± Sr
				2014	2015	2016	
Early hybrids	DKC 2960	S* (187 g)	4 cm	3.001	2.748	3.375	3.041 ± 0.315
			7 cm	3.162	2.804	3.178	3.048 ± 0.212
			11 cm	2.93	2.678	2.901	2.836 ± 0.138
		M** (238 g)	4 cm	3.763	2.811	3.6	3.392 ± 0.509
			7 cm	3.76	2.991	3.513	3.421 ± 0.393
			11 cm	3.627	2.968	3.479	3.358 ± 0.346
		L*** (277 g)	4 cm	3.659	2.803	3.722	3.395 ± 0.513
			7 cm	3.595	2.927	3.628	3.383 ± 0.396
			11 cm	3.637	3.041	3.756	3.478 ± 0.383
	DKC 2971	S* (194 g)	4 cm	2.938	2.805	3.413	3.052 ± 0.320
			7 cm	2.832	2.791	3.377	3.000 ± 0.327
			11 cm	2.746	2.658	2.918	2.774 ± 0.132
		M** (256 g)	4 cm	3.254	3.17	3.461	3.295 ± 0.149
			7 cm	3.227	3.047	3.56	3.278 ± 0.260
			11 cm	3.341	2.966	3.481	3.262 ± 0.266
		L*** (279 g)	4 cm	3.4	3.112	3.524	3.345 ± 0.211
			7 cm	3.364	3.03	3.635	3.343 ± 0.303
			11 cm	3.449	2.981	3.471	3.301 ± 0.277
Mid-early hybrids	DKC 3472	S* (249 g)	4 cm	3.374	3.181	4.497	3.684 ± 0.710
			7 cm	3.445	3.14	4.275	3.620 ± 0.588
			11 cm	3.345	3.109	4.098	3.518 ± 0.517
		M** (326 g)	4 cm	3.776	3.634	4.556	3.989 ± 0.497
			7 cm	3.779	3.527	4.619	3.975 ± 0.571
			11 cm	3.846	3.536	4.543	3.975 ± 0.516
		L*** (385 g)	4 cm	3.722	3.488	4.544	3.918 ± 0.555
			7 cm	3.812	3.587	4.475	3.958 ± 0.462
			11 cm	3.829	3.373	4.462	3.888 ± 0.547
	DKC 3795	S* (166 g)	4 cm	3.388	3.121	3.621	3.377 ± 0.250
			7 cm	3.258	3.169	3.558	3.328 ± 0.204
			11 cm	3.23	2.988	3.28	3.166 ± 0.157
		M** (207 g)	4 cm	3.679	3.627	3.93	3.745 ± 0.162
			7 cm	3.723	3.308	3.678	3.569 ± 0.228
			11 cm	3.808	3.364	3.736	3.636 ± 0.238
		L*** (287 g)	4 cm	3.782	3.688	3.948	3.806 ± 0.132
			7 cm	3.879	3.236	4.025	3.713 ± 0.420
			11 cm	3.865	3.41	4.05	3.775 ± 0.330
Mid hybrids	DK 315	S* (223 g)	4 cm	3.816	3.509	4.345	3.890 ± 0.423
			7 cm	3.901	3.477	4.247	3.875 ± 0.386
			11 cm	3.863	3.23	4048	3.714 ± 0.429
		M** (294 g)	4 cm	4.184	3.845	4.452	4.161 ± 0.304
			7 cm	4.366	3.841	4.574	4.260 ± 0.377
			11 cm	4.446	3.758	4.498	4.234 ± 0.413
		L*** (327 g)	4 cm	4.195	4.011	4.594	4.266 ± 0.298
			7 cm	4.496	3.932	4.671	4.366 ± 0.386
			11 cm	4.289	3.854	4.636	4.260 ± 0.392
	DKC 4082	S* (172 g)	4 cm	3.724	3.701	4.083	3.836 ± 0.215
			7 cm	3.779	3.617	4.062	3.820 ± 0.225
			11 cm	3.685	3.406	3.974	3.689 ± 0.284

	M** (227 g)	4 cm	3.971	3.923	4.691	4.195 ± 0.430
		7 cm	4.441	3.996	4.905	4.447 ± 0.455
		11 cm	4.625	3.89	4.843	4.453 ± 0.500
	L*** (278 g)	4 cm	4.088	3.903	4.457	4.149 ± 0.282
		7 cm	4.437	3.976	4.816	4.410 ± 0.421
		11 cm	4.488	3.904	4.753	4.382 ± 0.434

LSD05, t/ha Factor A– 0.124; Factor B-0.09; Factor C-0.306; Factor D-0.117.
-small seed fraction; **-medium seed fraction; *-large seed fraction.*

Seed fraction (factor C) also affected an approximate bioethanol output. In particular, on the average for three years of research, when applying small seed fraction bioethanol output ranged within 2.94-3.78 thousand l/ha, or the mean of 3.41 thousand l/ha for the fraction, when applying mid-size fraction-3.28-4.36 thousand l/ha, or the mean of 3.81 thousand l/ha for the fraction, and when applying large fraction-3.33-4.31 thousand l/ha, or the mean of 3.84 thousand l/ha for the fraction.
The seeding depth (factor D) had a mixed effect on bioethanol output from corn grain. Thus, shallow seeding (4 cm) provided bioethanol output, on the average for three years, within 3.23-4.11 thousand l/ha, or the mean of 3.697 thousand l/ha for this depth. Seeding at the depth of 7 cm provided 3.21-4.23 thousand l/ha, or the mean of 3.713 thousand l/ha, while deep seeding (11 cm) provided 3.11-4.17 thousand l/ha, or the mean of 3.648 thousand l/ha. Therefore, an increase in the seeding depth contributes to decrease in bioethanol output per unit of the cropping area.

Conclusions

It has been found that on the average for 3 years corn seed of mid hybrids appeared to be the most productive and provided a significant yield increase (DK 315- 9.96 t/ha and DKC 4082-10.03 t/ha).
The highest starch content in corn grain and hence bioethanol output during the research period was 75.40% in group of mid hybrid.
Shallow corn seeding is more cost beneficial, since increase or decrease in the seeding depth of around 7 cm promotes 0.20-0.51% reduction in starch content in corn grain. Shallow seeding (4 cm) contributed to bioethanol output within 3.697 thousand l/ha, seeding at the depth of 7 cm-3.713 thousand l/ha and deep seeding (11 cm)-3.648 thousand l/ha.
In addition, application of small seed fraction significantly increases approximate bioethanol output per unit of area under corn hybrids depending on the cultivation technology elements.
Therefore, search for the ways aimed to develop the elements of corn cultivation technology, which would ensure a significant increase in the yield and starch content, will regulate mass production and consumption of bioethanol in our state.

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