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THE BIOLOGICAL CHARACTERISTICS OF GRAIN PRODUCTION AND SILAGE FROM CORN (ZEA MAYS)

Abstract. Improvement of technology of cultivation of maize in the Northern Kazakhstan was based on the principles of soil-protective arable farming and harvesting silage was the main purpose. The advanced technology with the use of early-maturing hybrids (FAO (Food and Agriculture Organization) 150-199) on the basis of minimizing of the technological cycle has been developed in the North Kazakhstan Research Institute of Agriculture in the period from 1987 to 1997. The average output of absolutely dry substance for this period was 4.8 t/ha, that is 45.1% higher than in the previous period (1977–1986). However, the advanced technology based on the cultivation of the only silage crop (monoculture) cannot exclude a sharp decrease of the yields in droughty years and in years when the summer is short and cool. The silage conveyor as an alternative to monoculture of maize was substantiated by the selection of crops with different biological requirements for growth conditions. The yields of the silage conveyor crops (sunflower-maize-sweet sorghum) were 5.14 t/ha (absolutely dry substance), that is 0.73 t/ha higher than the yields of monoculture of maize in the period from 2007 to 2009.

Key words: maize, silage, fodder, grain, early maturing hybrids, dry substance, the cultivation technology, methods of cultivation, crop productivity, silo conveyor, monoculture, the Northern Kazakhstan.

Introduction. Maize cultivation in the northern regions of Kazakhstan originates from the 1950s when the maize began to sow to produce silage. The large areas were sowed for the first time (more than 75 thousands of hectares) in 1954 and the areas about 1.5 mln hectares, which is 2/3 of the total area of Kazakhstan, were sowed in the next 5 years [1, 2].

Large-scale introduction of maize and implementation of tilled farming system were carried out simultaneously. The maize field was the main one in crop rotations in this farming system [3].

The introduction of maize was carried out rapidly and over the large areas, so the zonal features of the new region of cultivation were not taken into account. Agricultural techniques, the system of agricultural implements and hybrids of maize were carried over unchanged. Agro techniques were based on late-ripening hybrids and the use of moldboard plowing, disk plough-harrows and checkrow planting ensured the ability of two inter-row processing in two directions during the period of vegetation.

Such unreasonable transfer of a tilled technology into the steppe zone, not protected from destructive influence of wind, led to the widespread deflation and systematic damage of the plants in the fields [4, 5].

The agricultural science faced a challenge of development of soil-protecting activities to overcome destructive influence of drought, wind erosion. These methods would guarantee the preservation of soil fertility. However, there were positive results. A practical expediency and economic efficiency of maize cultivation to harvest silage on the basis of imported seeds was proven during the period of introduction of maize in the Northern Kazakhstan [6-8].

Dairy farming was now based on a fundamentally new type of feeding in virgin areas. The basis of the ration was silage and concentrates [9]. Scientific research of that period lasted until 1986. Soil-

protective technologies were specified for each agricultural zone. The main tasks of the scientific research were to protect the plants in the fields from wind erosion and a decrease in the amplitude of fluctuations of the yields of maize. Researchers of the Northern Kazakhstan have proven that maize is not a tilled crop and there is no need for continuous loosening of row-spacing [10, 11].

Agro-physical parameters of the soil after plowing do not meet the biological requirements for the growth of maize. This fact was experimentally determined for the first time in the conditions of Northern Kazakhstan. When the density of the soil in the rooting zone is 1.05-1.1 g/cm^3, the optimum water, air and food mode for the root system is created [12, 13], whereas after the plowing it is 0.9-0.95 g/cm^3. Full substantiation of this theory was given by scientists of Agrophysical Scientific and Research Institute (Russian Federation) and in the countries of Western Europe [14, 15].

Materials and methods. The trends in change of the yields for a period of 1969-1986 were determined on the basis of statistical reporting in the administrative districts, which are included in the appropriate agricultural zone. Mathematical processing of data was performed by the method of equal squares [16].

The analysis of the chemical composition of the biomass was performed according to the conventional technique:

– the protein content - by the method of Kjeldahl;
– the determination of cellulose - by the method of Ganneberg-Shtoman;
– the determination of sugars - by the centrifuge micromethod of Bertrand-Bieri;
– the determination of crude fat - by extracting with ethyl ether;
– the definition of carotene - on the SF-596 spectrophotometer.

Results and discussion. Soil-protective farming system included new crop rotations with the "corn-wheat" crop group. The highest yield (absolutely dry substance) per 1 ha was obtained in this group.

Wide-row method of sowing (70 cm) has become an alternative to a checkrow sowing, where the integrated protection of maize was carried out by applying of soil herbicides and surface treatment the most littered plots on the field. A distinctive feature of the soil-protective technologies that had already been developed was at the zonal level, to minimize a technological cycle by consolidating of manufacturing operations, increasing the width of capture of units and decreasing of the depth of processing.

We carried out a comparative assessment of energy consumption for a tilled technology (during the period OF 1969-1976) and for a soil-protective technology (during the period OF 1977-1986) at the experimental field of the North-Kazakhstan Scientific and Research Institute of Agriculture. The experimental field is located in agricultural steppe zone of the Northern Kazakhstan. Abandoning the plough began to use the cultivator and this led to increased productivity of labor and to reducing of material resources. The maize seeder has been upgraded for stable operation after treatment of the ground with a cultivator and performed a number of operations in a single pass: seed placement, fertilizing, introduction of soil herbicides and soil loosening in the row zone [17].

Thus, the number of passes on the field has decreased almost by half (table 1).

A labor costs per unit of area has decreased respectively. The average yield for the period of improving soil-protective technology (1977-1986) increased 1.5 times in comparison with the previous period (1969-1976) and amounted to 3.3 t/ha (absolutely dry substance).

However, soil-protective technology did not guarantee an annual maturation to milky-wax ripeness. Only in this phase maize is the standard raw material (more than 25% of absolutely dry substance) for the production of high-quality silage [18].

There are not enough effective temperatures for late-maturing hybrids to reach the milky-wax ripeness until the autumn frosts in the climatic conditions of the Northern Kazakhstan.

The dynamics of the yield of maize in selected agricultural areas during this period and quality of the yield can be seen in a typical example of the North-Kazakhstan region. We analyzed the maize cultivation in the region by the equal squares method during the 17-year period.

As convincingly demonstrated by mathematical analysis (table 2), in all agricultural areas during the period of years 1969-1986 the transition to soil-protective technology has affected the trend of growth of the yields, expressed as a positive value of the parameter x (average annual factor).

Table 1 – The technological cycles in the different periods of cultivation of maize at the experimental field of the North-Kazakhstan Scientific and Research Institute of Agriculture

Technological operation	Technology	
	Tilled (1969-1976)	Soil-protective (1977-1986)
Ploughing	+	–
Treatment of the ground with a cultivator	–	+
Harrowing with spike-tooth harrows	+	–
Harrowing with needle harrows	–	+
Treatment of the ground by disk plough-harrow before sowing	+	–
Treatment of the ground with a cultivator before sowing	–	+
Packing soil before sowing	+	–
Checkrow planting	+	–
dotted sowing with fertilizers and herbicides	–	+
Packing soil after sowing	+	–
Double harrowing	++	++
Treatment of soil in row-spacing	+	+
Treatment of soil in row-spacing with introduction of fertilizers	+	–
Treatment of soil in row-spacing crosswise the direction of sowing, 2 passes	++	–
Treatment of plants with herbicides	+	–
Harvesting	+	+
The number of treatments	14	8
The average yield for the period, t/ha	2.2	3.3

Table 2 – The tendency in dynamics of the yield of maize in agricultural areas of the North-Kazakhstan region (during the period of years 1969-1986)

Agricultural zone	The tendency in dynamics of the yield	Yield		
		Natural humidity, t/ha	Absolutely dry substance	
			Concentration, %	Yield, t/ha
Moderately arid steppe	92.6 +4.4 x	14.9	20.4	3.03
Arid steppe	76.0 +5.5 x	13.2	23.0	3.03
Forest-steppe	112.0 +1.5 x	13.6	21.4	2.91
Hilly steppe	121.0 +2.7 x	15.6	19.5	3.04
Steppe on chernozem soils	105.0 +2.3 x	13.4	19.2	2.57
Steppe on chestnut soils	37.9 +2.2 x	7.09	20.0	1.41
Experimental field of The North-Kazakhstan Scientific and Research Institute of Agriculture (hilly steppe)	169.3 +5.7 x	22.6	23.1	5.22

Despite the fact that high technological discipline was maintained on the experimental field, as evidenced by the highest yield here, there was no guarantee for the milk-wax ripeness also on this field. The concentration of absolutely dry substance was lower than 25% that did not provide a producing of high-quality silage.

The concentration of absolutely dry substance in mid-season hybrids (FAO 200-250) which have been approved for use in the Northern Kazakhstan was reaching 20-23% before the first frost. The main cause of low-quality silage is the biomass with high humidity.

Since 1987, the team of scientists of the North-Kazakhstan Scientific and Research Institute of Agriculture started to develop an improved technology. This technology was based on the introduction of early-maturing hybrids (FAO 150-199). These hybrids had milky-wax ripeness every year in this region [19].

The yield of early-maturing hybrids was higher than that of the mid-season hybrids, as was proven by our research and confirmed by verification in production. It is well known that the maximum daily gain of maize falls on the phase of milky-wax ripeness and significantly exceeds the rates of all the previous phases [20-24].

Early maturing hybrids grow intensively 12-15 days until frost, while for the mid-season hybrids this period is 1-3 days and is interrupted by frost. Therefore, the mid-season hybrids which have a higher potential of productivity in comparison with the early-maturing hybrids, inferior to them in the yield of absolutely dry substance in the short summer.

The average yield for the 1987-1995 period was higher (advanced technology) than for the prior periods (figure 1).

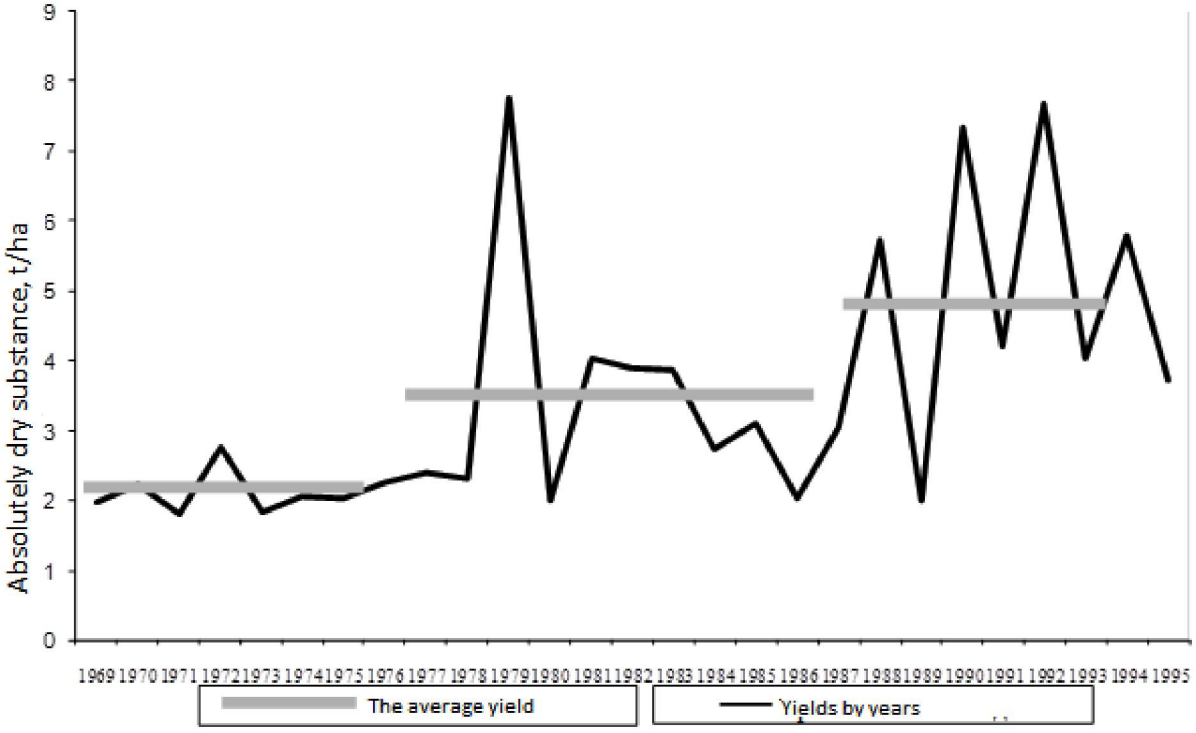

Figure 1 – Dynamics of the yield of maize in the experimental field
of the North-Kazakhstan Scientific and Research Institute of Agriculture as shown by the periods of cultivation

However, the improved technology does not guarantee the annual high yields in difficult climatic conditions of the Northern Kazakhstan. Maize was the main silo crop in the region, other silage crops occupied 6-17% of the total area.

Therefore, fluctuations in yield depended only on one culture. Maize harvest is increasing slowly in years with cool summers; the moisture content of the plants will be high. Maize also gives low yields in dry years (table 3).

To the main silo crop needs a set of other cultures for a particular agricultural zone. This set of other cultures will reduce the fluctuations of annual yield. Average yield of these crops should be higher than the yield of maize. In this case, we obtain the optimal set of crops [25].

The optimal period for harvesting of maize corresponds to the phase of milky-wax ripeness and lasts 8-10 days. In fact, this period lasts 18-20 days, if maize is a monoculture. Therefore, harvesting silage ends, usually at subzero temperatures, which affect the quality of biomass.

Table 3 – The amplitude of fluctuations of yield of maize in the experimental field of the North-Kazakhstan Scientific and Research Institute of Agriculture

Year	The sum of temperatures above +10°C, °C	The amount of precipitation (May-August), mm	The period without effective rainfall, days	Absolutely dry substance, t/ha	The decrease in yield, t/ha
1987	1775	132.2	30.VI – 7.VII (37)	3.0	1.8
1988	2120	129.3	27.VI – 10.VII (15)	5.7	–
1989	2178	133.1	27.VI – 21.VIII (51)	2.0	2.8
1990	2077	304.2	29.V – 15.VI (16)	7.3	–
1991	2124	132.2	31.V – 7.VII (37)	4.2	0.6
1992	1890	281.4	8.VI – 21.VI (12)	7.6	–
1993	1951	238.9	3.VI – 5.VII (32)	4.0	0.8
1994	1960	287.6	20.VI – 7.VII (16)	5.8	–
1995	1627	122.4	20.VI – 9.VII (19)	3.7	1.1
1996	1886	219.0	21.VI – 8.VII (16)	4.8	–
1997	2230	144.0	17.VI – 5.VII (18)	4.7	0.1
1987-1997	1983	194.5	(24)	4.8	
Note: Rainfall of more than 5 mm per day classified as effective.					

Typical results were obtained by us in 1996, when the first frost was on August, 26 (table 4).

Table 4 – Chemical composition of maize in different periods of harvesting (1996)

Indicators of the quality of the yield	Unit of measu-rement	Period of harvesting		
		Milk ripeness	Milky-wax ripeness	
			Before the frost	After the frost
Date of sampling		20.VIII	25.VIII	30.VIII
Humidity	%	79.3	75.3	77.8
Absolute dry substance	%	20.7	24.7	22.2
Including				
protein	%	3.0	2.6	2.5
Fat	%	0.4	0.8	0.2
cellulose	%	7.4	6.9	11.5
nitrogen-free extractives	%	8.0	12.6	6.6
Ash	%	1.9	1.8	1.4
The amount of carotene	mg / kg	23.5	15.9	8.6

The researchers had to find the set of crops in the system of silage conveyor to decrease the amplitude of harvest variations over years with extreme conditions. At the same time maize should remain the main silo crop. The results of the research (1998-2006) showed that in years with cool summers, when the number of active temperatures is insufficient, sunflower gives the greatest yield. The yield of sugar sorghum is much greater than yield of maize and sunflower in dry land conditions when the period of vegetation is prolonged [25].

The yield of maize, sweet sorghum and sunflower differ from each other and depended on the period of harvesting (table 5).

Yield of sunflower, compared with yield maize and sorghum, had the maximum value on the 25 of August. Because the maize did not reach milk-wax ripeness yet, as well as sorghum did not reach the stage of flowering. Maize reached milky-wax ripeness on the 30 of August, and on this day, the yield of maize was higher than that of sunflower and sugar sorghum. In turn, sweet sorghum reached its maximum yield in the first five days of September.

Table 5 – The yield of silage crops by calendar dates (absolutely dry substance), t/ha

Year	Date of harvesting			
	August, 20	August, 25	August, 30	September, 5
Maize (control)				
2007	18.2	40.1	48.0	–
2008	30.2	62.3	68.4	–
2009	24.6	50.3	55.5	–
2007-2009	24.0	50.2	57.3	–
Sun flower				
2007	59.1	65.2	–	–
2008	38.3	45.0	–	–
2009	49.5	56.9	–	–
2007-2009	48.0	55.0	–	–
Sweet sorghum				
2007	19.3	24.5	26.3	38.5
2008	24.5	36.0	47.6	69.2
2009	22.4	35.2	44.7	62.4
2007-2009	21.0	31.2	39.6	56.7

The interpretation of these data allows to calculate the yield of silage crops in the system of silage conveyor, if the harvesting period fits: for sunflower - August, 20-25 (flowering stage); for maize - August, 26-30 (milky-wax ripeness), sweet sorghum - August, 31 – September, 5 (flowering of panicles).

We compared the average yield of crops in the system of silage conveyor (maize, sunflower and sugar sorghum) with a yield of monoculture of maize over 3 years (2007-2009). It was found (table 6) that the amplitude of fluctuation of yield for the monoculture of maize was higher from year to year. The average yield of monoculture (2007-2009) was lower, because the harvesting period was prolonged. Harvesting of monoculture of maize began before reaching the milk-wax ripeness.

Table 6 – Comparison of different systems for the production of silage

The system of the production	2007	2008	2009	2007-2009
Monoculture of maize, t/ha	3.54	5.36	4.34	4.41
The deviation from the mean value				
t/ha	- 0.87	+ 0.95	- 0.07	–
%	- 19.7	+ 21.5	- 1.5	
The system of silage conveyor, t/ha	4.61	5.51	5.32	5.14
The deviation from the mean value				
t/ha	- 5.53	0.37	0.18	
%	- 10.3	+ 7.1	+ 3.5	

The yield of crops in system of silage conveyor will be higher if corn, sunflower and sweet sorghum do (no “will” after “if”) not occupy equal areas. They should occupy the acreage according to the probability of occurrence of certain weather conditions.

It was established by us that the number of years with high solar activity and prolonged summer in the hilly-steppe zone was 8 of 30 (1961-1990). Therefore, the acreage of sweet sorghum should be no more than 25%, which corresponds to the theoretical frequency of coming of favorable years. The theoretical frequency of coming of favorable years for sunflower corresponds to 25-27%.

Conclusion. Scientific search has developed from tilled technology to soil-protective and further to advanced technology on the principles of the increasing yield, the quality of yield and minimizing of the technological cycle during the 5 decades of cultivation of maize in the Northern Kazakhstan.

The average yield was 4.8 t/ha (absolutely dry substance) over the years of the introduction of improved technology (1987-1997) at the experimental field of the North-Kazakhstan Scientific and Research Institute of Agriculture. Yields increased 2.2 times compared to the tilled technology (1969-1976). Labor costs decreased 4.9 times per 1 ton of product.

Silage conveyor was developed on the basis of the set of crops, which supplemented maize, for production of sustainable by years raw material silage. Yields of maize as a monoculture for production of silage amounted to 4.41 t/ha during 2007-2009, that is 0.73 t/ha less than the average yield of crops of the system of silage conveyor (sunflower - corn - sugar sorghum). The amplitude of fluctuation of yield decreased from 19.7% (monoculture) to 10.3% (silage conveyor).

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ЖҮГЕРІДЕН АСТЫҚ ПЕН СҮРЛЕМ ӨНДІРУ БИОЛОГИЯЛЫҚ ЕРЕКШЕЛІКТЕРІ

Аннотация. Солтүстік Қазақстанда жүгері өсірудің технологиясын жетілдіру топырақты қорғау және сүрлем дайындау принципте негізделеді. Ерте пісетін будандарды қолдана отырып (ФАО (Азық-түлік және Ауыл шаруашылығы Ұйымы) 150-199) технологиялық циклды азайту негізінде озық технология Солтүстік Қазақстанның ауыл шаруашылығы ғылыми-зерттеу институтында 1987-1997 жылдары әзірленді. Осы кезеңде абсолютті құрғақ заттардың орташа шығуы 4,8 т/га құрайды, 45,1%-ға алдындағы кезеңнен артық (1977–1986 жж.). Алайда, озық технологиялар сүрлемге өсіруге ғана (монодақыл) негізделген. Сондықтан, жазы қысқа, салқын және құрғақшылық жылдары өнімділіктің күрт төмендеуі де байқалуы мүмкін. Сүрлемдік конвейерде жүгері монодақылға альтернатива ретінде өсу жағдайларына сәйкес әртүрлі биологиялық талаптарымен дақылдардың таңдауы негізделген. Сүрлемдік конвейерде дақылдардың өнімділігі (күнбағыс-жүгері-шай жүгері) 5,14 т/га құрады (абсолютті құрғақ зат бойынша), ол 2007 жылдан 2009 жылға дейін кезеңіндегі құралған жүгері монодақыл өнімділігінен 0,73 т/га жоғары болды.

Түйін сөздер: жүгері, сүрлем, жемшөп, астық, ерте пісетін будан, құрғақ зат, өсіру технологиясы, өсіру әдістері, өнімділік, сүрлемдік конвейер, монодақыл, Солтүстік Қазақстан.

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БИОЛОГИЧЕСКИЕ ОСОБЕННОСТИ ПРОИЗВОДСТВА ЗЕРНА И СИЛОСА ИЗ КУКУРУЗЫ

Аннотация. Совершенствование технологии выращивания кукурузы в Северном Казахстане основывается на принципах почвозащитного земледелия и заготовки силоса. Передовая технология с применением раннеспелых гибридов (ФАО (Продовольственная и Сельскохозяйственная Организация) 150-199) на основе минимизации технологического цикла была разработана в Северо-Казахстанской научно-исследовательского института сельского хозяйства в период с 1987 по 1997 год. Средний выход абсолютно сухого вещества за этот период составила 4,8 т/га, что составляет 45,1% больше, чем за предыдущий период (1977–1986). Однако передовые технологии основывались только на выращивании на силос (монокультура). Вследствие этого нельзя исключить резкое снижение урожайности в засушливые годы и в годы, когда лето короткое и прохладное. В силосном конвейере в качестве альтернативы в монокультуре кукурузы был обоснован выбор культур с различными биологическими требованиями к условиям роста. Урожайность культур в силосном конвейере (подсолнечник-кукуруза-сорго) была 5,14 т/га (абсолютно сухое вещество), что составляет 0,73 т/га выше урожайности монокультуры кукурузы в период с 2007 по 2009 год.

Ключевые слова: кукуруза, силос, фураж, зерно, раннеспелый гибрид, сухое вещество, технология выращивания, методы выращивания, урожайность, силосный конвейер, монокультура, Северный Казахстан.