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Power-saving agro-technology of production of grain of corn on irrigated lands

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The purpose. To study effect of minimization of soil cultivation and different ways of importation of fertilizers upon efficiency of agro-technology of production of grain of corn on irrigated lands of Steppe of Ukraine. **Methods.** Long-term field experiments, agrochemical analyses of soil and plants, phenological observations over growth and development of plants of corn, harvesting and account of grain yield with statistical analysis of data are carried out. **Results.** The maximum productivity of grain of corn (on the average for 3 years) was gained at importation of $N_{9}0P_{45}$ with irrigation water in phase of 10 – 12 leaves and in phase of ejection of brushes — 10,4 t/hectare. Dose of fertilizers $N_{180}P_{90}$ is better paid for itself by increase of productivity at its importation in 2 times by equal parts in phases of 10 – 12 leaves and ejection of brushes (on $N_{90}P_{45}$). **Conclusions.** Minimization of soil cultivation, importation with irrigation water of means of chemization, use power-saving sowing campaigns, irrigation, harvest and transport equipments of mechanization will enable to lower power inputs on production of grain of corn at irrigation minimum on 35 – 40 %, having converted in such a way intense energy-dependent technique of growing into power-saving. The opportunity of synchronous optimization of water regime of plants and their security with readily available shapes of nutrients at stages of organogenesis is realized. Application of the developed technique will enable to gain high productivity of grain of corn in conditions of irrigation at optimum overlapping agrotechnical methods and intelligent use of irrigation water, fertilizers, power and material resources.

Key words: *corn, agro-technology, fertilizers, soil cultivation, fertilization, minimization of machining, productivity of grain.*

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Corn is one of the main grain and forage crops. Expansion of its crops on irrigated lands of Ukraine, creation of zones of guaranteed grain production is an important production reserve, since it uses the potential of irrigated lands most efficiently from cereals [1].

In the farms of Ukraine with a high level of culture of irrigated agriculture, the grain yield of corn did not exceed 11-12 t/ha in the last twenty years. At the same time, on the irrigated land in California (USA), on some farms, the grain yield of corn from 1981-1983 ranged from 18.2 to 20.0 t/ha, and in Michigan it reached 22.1 t/ha. Record yields - 23.2 t/ha were obtained in 1985 in the state of Illinois on the farm Nermosh Vorsovi [2].

The main reason for this situation in Ukraine was due to the growth in prices of the main types of energy carriers (gas, oil, fuel and lubricants, electricity) in recent decades. The energy intensity of corn grain production remains high.

We were tasked with developing the energy-saving agrotechnology of corn grain production on irrigated lands in the conditions of the northern Steppe of Ukraine. In the first place, it is necessary to propose to the manufacturer effective minimization of soil cultivation in irrigated crop rotations, to synchronize the irrigation regime of various hybrids of corn while simultaneously introducing mineral fertilizers with irrigation water.

The modern system of intensive cultivation of soil in irrigated agriculture is based on the creation of optimal conditions in the arable layer of soil. According to the results of earlier studies, it has been established that for soil of medium and heavy mechanical composition for the development of maize plants, the optimum soil density parameters should be within the limits of 1,1-1,2 g/cm^3 , the total jointing – 50-55 %, the arability of aeration in the field permeability of at least 60 mm/h and field moisture content – 30-33 %. Such an arable layer is created by different methods of cultivating soil [3]. It is generally accepted that after each irrigation, "to close the moisture" requires loosening of the soil regardless of the presence of weeds. Primary cultivation plays a major role in creating favorable physical conditions for the formation of soil fertility and continues to be one of the most important ecologically safe measures to control weeds, pests and diseases of agricultural crops [4].

In optimizing soil cultivation, it should be aimed at reducing labor costs, reducing the rate of mineralization of organic matter, as well as preventing degradation processes and preserving soil fertility [5].

In our experiments, when the moisture content of the soil was maintained by spraying in non-plant plots (without loosening, without cultivation and holding five cultivations), at a level of 80 % MWC (minimum water capacity) in the soil layer 0-50 cm, no difference in soil moisture content was observed [6]. These studies succeeded in challenging numerous mechanical methods of cultivating soil when irrigating and explaining this issue in the work of A.M. Alpatiev [7]. He found that the evaporation of water by soil with optimal moisture content approaches the evaporation rates from the water surface and does not depend on the type of plants, plant density, the shape of the surface of the field, but only changes under the influence of meteorological factors and weather conditions (wind, sun, air temperature, etc.).

This phenomenon makes it possible to argue that for this reason, all methods of cultivating soil at its moisture above the bursting of capillaries do not give effect, and the size of physical evaporation depends on the temperature and wind speed. If soil moisture drops below the capillary gap, then the mechanism of diffuse loss of moisture operates [7].

In experiments to minimize irrigated soil tillage in the conditions of Ukraine and Moldova we compared cultivation and milling and their impact on soil moisture. The differences between these methods of soil cultivation have not been established [6].

The effectiveness of minimizing soil cultivation depended on soil cover characteristics. In Moldova, when cultivating corn on irrigated sloped lands, plowing was effective at a depth of 30-32 cm, while in the system of pre-planting it was chiseling at a depth of 16-18 cm with subsequent decanting. In combination with irrigation rates of 350-400 m^3/ha and optimal doses of mineral fertilizers received 50-60 t/ha of hybrid mass of the maize VIR-156 and completely excluded irrigation erosion [6].

The traditional technology of introducing mineral fertilizers in irrigated agriculture was mechanically transferred from non-irrigated agriculture, where, with the help of trailed or attached centrifugal spreaders, fertilizers are distributed along the surface of the field, with subsequent tillage into the soil by means of plowing, cultivation, or harrowing. In this way, you can make any amount of fertilizer, due to its advantages: high productivity, ease of maintenance of mechanization, the possibility of using high-humidity tufts, a wide range of fertilizers. But this method also has significant drawbacks that consist in the fact that most of the fertilizers are not introduced into the soil, but are scattered on the surface of the field, while being rather uneven [2,8,9].

Currently, the majority of machines for surface application of mineral fertilizers are equipped with plate and disk centrifugal mechanisms that unevenly distribute fertilizers by the width of the aggregate capture. In the production environment, the unevenness of fertilizer often reaches 60-80%, which reduces their efficiency: nitrogen – 45-50 %, phosphorous – by 15-20 %, potash and complex – by 30-40 % [9].

Studies conducted in the United States showed that as a result of uneven fertilization, the grain yield of maize varied from 52.1 to 106.8 centners per hectare, with an average value of 78.5 centners per hectare. This fact confirms the opinion that due to the uniform optimal supply of plants by nutrients, the grain yield can be increased by 28 centners per hectare [10].

The unevenness of fertilizing (even with unbreakable properties) by some spreaders reached 30 %, which caused significant shortages of crop. In Germany, deviations from the norm are considered to be satisfactory not more than 10 %, and maximum not more than 20 % [11].

For the introduction of higher standards of fertilizers, the requirements for their uniformity of distribution increase, and in such conditions, the use of centrifuge scatterers is prohibited [12].

Uneven spreading, especially excessive amounts of fertilizers, leads to inappropriate use, negative effects not only on plants but also on soil (excess of nutrients in one and the absence of other places, nitrate contamination, etc.), which often can not be corrected. The application of heavy and powerful machine-tractor aggregates for surface fertilization causes over-compaction of the upper layers of soil, worsens its physical properties, reduces grain yield of corn, increases the cost of soil cultivation [14].

As the study showed, the yield of corn grain decreased by 4.5-9.3 centners per hectare in a two-way passage along the same trace of tractors T-150 K and ЮМЗ-61 [3].

Mineral fertilizers are produced and sold quite rhythmically, therefore, those that come to consumers during the growing season of maize, remain virtually unused. This is due to the fact that the use of propelled cultivators for cultivating fertilizers is limited to the onset of the period of the closure of corn plants in rows. In addition, frequent refueling of small containers for fertilizers on cultivators is associated with additional labor costs.

It is for these reasons that an intensive corn-growing technology is increasingly using a progressive way of introducing mineral fertilizers along with irrigation water, called "fertigation", or fertilizer irrigation. The introduction of fertilizers simultaneously with watering creates an opportunity to optimize the supply of plants with moisture and easily accessible forms of nutrients almost throughout the growing season. Fertigation radically solves the problem of even distribution in the area of fertilizers in the active layer of soil to the level of uniformity of distribution of irrigation water, estimated by the coefficient of variation of no more than 20 %. In addition, an important advantage of this method is the possibility of feeding small quantities of fertilizers during the growing season when plants are most in need of it, without damage to the leaves, both mechanically and through chemical burns [6,8].

Fertigation with the use of modern sprinklers allows to abandon tractor spreaders, reduce the number of technological operations, improve the efficiency of using irrigation techniques and fertilizers. This creates conditions for saving labor, money and energy [2,6,8,9].

This method allows combining operations such as fertilizer application, herbicides, trace elements, vegetative irrigation, performing operations with fewer passes through the field of heavy and powerful tractors with trailer trailers, fertilizer spreaders, sprayers and other deforming soil mechanization means.

According to studies conducted at the Institute of Cereals of the National Academy of Sciences of Ukraine, the highest effect was achieved by combining the traditional method of fertilizing and fertigation, according to the estimated fertilizer rates for the planned grain yield of 10 t/ha [6].

Table 1. Corn grain yield, depending on the method of making mineral fertilizers, t/ha

№ p	Method of making mineral fertilizers	Hybrid Dnieper 758		Hybrid Pioneer 3978	
		Year			
		1984	1985	1984	1985
1	NPK under cultivation before sowing	10.7	9,2	10,7	9,6
2	NPK + LCF * with irrigation water after sowing	10,9	9,7	10,7	10,4
3	NPK under cultivation before sowing + LCF * with irrigation water	11,3	10,1	11,4	10,8

Note: LCF * - liquid complex fertilizers.

Combined use of fertilizers (NPK - dry tillers for cultivation before sowing + LCF with irrigation water after sowing) proved to be better than fertigation with efficiency (crop growth was 0.39-0.55 t/ha).

Our studies have confirmed that for a hybrid of maize Dnieper 758 on black soil, the usual medium-loam NPK with irrigation water is preferable to dry tillers for cultivation before sowing (Table 2).

Table 2. Influence on the productivity of the hybrid of corn Dnieper 758 terms and methods of fertilizing with irrigation water (1986-1998)

№ p	The method and the line fertilizer	Grain yield, t/ha	Increase in yield, t/ha	The grain is obtained in a rate of 1 kg per day NPK, kg
1	NPK for cultivating superficial dry tuk (control)	9,64	-	3,89
2	NPK with irrigation water after sowing	9,95	0,31	4,01
4	P and K to full dose sowing, N-½ doses in the phase of 10-12 leaves, ½ in the phase of discharging the vagrants.	10,4	0,76	4,19
5	The same, but N-1/3 after sowing, 1/3 - in the 10-12 leaf stage, 1/3 - in the ejection phase panicle	10.62	0,98	4,31
6	The same, but N- full dose in the phase of throwing panicle	10.19	0,55	4,11

In experiments on crop programming at the level of 10 t/ha doses of mineral fertilizers were: in 1986 – $N_{168}P_{90}K_{28}$; in 1987 – $N_{192}R_{70}K_{27}$; in 1988 – $N_{136}R_{35}$.

The maximum yield – 10.6 t /ha (Table 2) was obtained on the background of the introduction of phosphorus and potassium fertilizers for cultivation; Nitrogen fertilizers were added together with irrigated water in equal proportions after sowing, in the phase of 10-12 leaves and in the phase of discharging the vagrants.

The purpose of the research. To study the influence of minimization of soil cultivation and different ways of introducing mineral fertilizers on the efficiency of agrotechnology of corn grain production on the irrigated lands of the Ukrainian Steppe.

Materials and methods of research. The research was carried out during 2002-2004 in the educational and research farm "Samara" of the Dnipropetrovsk State Agrarian University (now the Dnipro State Agrarian and Economic University).

The soil of the experimental site – black earth is a simple low-humus weak-tempered medium-grained. The volumetric mass of the soil layer is 0-70 cm is 1.28 g/cm^3, and the lowest moisture content (MWC) – 21.5 %. The thickness of the humus layer is 65-70 cm, and the content of humus in the arable soil layer of Tyurin is 2.0-3.5 %. After nitrogen nitrogen after 7 days of composting (according to Kravkov), in 100 g of dry soil there were 2.4-3.8, mobile phosphorus (in an octo-oxide extract according to Chirikov) – 10.9-15.5, exchangeable potassium (according to Maslova) – 20-24.4 mg /100 g of soil. Subsoil waters lie at a depth of more than 15 m. Sown area of experimental sites – 630 m^2, accounting – 150 m^2, repetition - 4 times.

Weather conditions during the years of research were generally favorable for growing corn under irrigation conditions. During the vegetation period (May-September) in 2002, 332 mm of rain fell, in 2003 – 303 mm, and in 2004 – 386 mm.

In experiments, medium-sized corn hybrid Pioneer 3978 was sown, which responded well to irrigation and was the object of research. The lines and methods of making mineral fertilizers were studied at the calculated dose for the receipt of grain yield of 10 t/ha. There was also an option without fertilizers. Corn cultivation technology was commonly used for this crop in the northern steppe region of Ukraine. The pots were driven by a drainage unit DDA-100MA. Mineral fertilizers were dosed in irrigation water with a special hydro injector. The irrigation mode provided for the maintenance of soil moisture in the active layer of not less than 70-80 % MWC. The irrigation rate was 1500-2000 m^3/ha.

From liquid mineral fertilizers (LCF) the nitrogen-phosphorous solution was used at 10:34 (N – 10 %, P – 34 %), obtained by neutralizing polyphosforic acids with ammonia.

Doses of mineral fertilizers for obtaining the planned grain yield of corn 10 t/ha were calculated by the balance method taking into account the content of the main nutrients in the arable soil layer. Estimated doses were $N_{180}P_{90}$.

In order to study the efficiency of introducing liquid complex fertilizers with irrigation water, different variants were developed in comparison with the traditional spreading method and the determination of optimal parameters of fertigation in the cultivation of maize on grain.

Technological schemes for the introduction of mineral fertilizers were as follows:

1 - under cultivation before sowing (urea + ammophos), intestines with full norm of $N_{180}P_{90}$ (control);

2 - under cultivation before sowing (urea + LCF) with full norm of $N_{180}P_{90}$ (control);

3 - retail with irrigated water $N_{60}P_{30}$ after sowing and $N_{120}P_{60}$ in the phase of 10-12 leaves;

4 - retail with irrigation water: after sowing $N_{50}P_{25}$; in the phase of 10-12 leaves of $N_{50}P_{25}$; in the phase of discharging the vagrants $N_{40}P_{20}$; in the phase of milk ripeness of grain $N_{40}P_{20}$;

5 - retail with irrigation water: in the phase of 10-12 leaves $N_{60}P_{30}$; in the phase of discharging the vagrants $N_{60}P_{30}$; in the phase of milk ripeness of grain $N_{60}P_{30}$;

6 - retail with irrigation water: in the phase of 10-12 leaves of $N_{90}P_{45}$ and in the phase of discharging the vagrants $N_{90}P_{45}$.

Also in the experiments a control version was foreseen without fertilizers. Under the first scheme, urea and ammophos were introduced before cultivation. For the second and all the following (with irrigation water), in order to equalize the content of nitrogen and phosphorus to the estimated dose of liquid complex fertilizers added urea.

Research results. The rules and timing for the introduction of liquid complex mineral fertilizers with irrigation water significantly influenced the nutrient regime of the soil. Favorable conditions of humidity and temperature significantly improved the nitrogen regime of the soil due to fertilizers and increase the nitrification capacity. The maximum amount of mineral nitrogen in the soil has been marked at the beginning of the vegetation when the tufts are applied for cultivation, which suggests an increase in the energy of nitrification.

Considering the content of mineral nitrogen in dynamics, its reduction in the soil from the phase of 5-6 leaves to the milk ripeness of the grain was marked, indicating a significant consumption of nitrogen by maize in the main phases of ontogenesis. In the period of intense need of corn plants in nitrogen (10-12 leaves) NO_3 – in the soil was less than in the period of 5-6 leaves at 32 %, and in the phase of milk ripeness of grain – by 62.4 %. In the non-fertilized variant, the same tendency was observed for the reduction of nitrate nitrogen in the soil (by 29.8 % and 50.8 %, respectively).

This was due to the intensive growth of nitrification processes in the soil due to the creation of optimal conditions (soil moisture was not less than 70-80 % MWC, air temperature during vegetation 20-25°C, good aeration) and low consumption of corn plants NO_3 at the beginning of vegetation. At the same time, when using fertilizers with the dose of $N_{180}P_{90}$, along with irrigation water, the volatility of nitrates in the soil in this period was lower and moreover, they were contained, in particular in the phase of milk ripeness of grain, much more that had a positive effect on yield. The introduction of mineral fertilizers with irrigated water in two terms into a phase of 10-12 leaves and in the phase of discharging volatile $N_{90}P_{45}$ dose provided the maximum amount of nitrate nitrogen in the milk ripeness phase of the grain.

In the phase of full ripeness of corn grain, both in fertilizing irrigation and fertilizers, the amount of mineral nitrogen in the soil was almost identical.

On all fertilized backgrounds, the number of productive tubers was almost identical, but the absolute mass of grains at the same time differed (Table 3). It was much bigger for the fertilizing of the farm with irrigation water.

Table 3. Productivity of the hybrid Pioneer 3978 depending on the methods and terms of mineral fertilizers (average for 2002-2004)

Variant	The number of productive cobs per 100 plants	Mass of a single chimney, g	Grain yield, %	Weight of 1000 grains, g
No fertilizer (control)	98	190	79,9	265,5
$N_{180}P_{90}$ (urea + ammophos) sprouts in the spring under cultivation	102	225	79,4	286,6
$N_{180}P_{90}$ under cultivation before sowing (urea + LCF) with irrigation water	103	225	80,6	282,6
$N_{60}P_{30}$ with irrigation water after planting and 10-12 in phase $N_{120}P_{60}$ leaves	102	230	79,6	298,4
with irrigation water: after sowing $N_{50}P_{25}$; in the phase of 10-12 leaves $N_{50}P$ in the phase of discharging the vagrants $N_{40}P_{20}$; in the phase of milk ripeness of grain $N_{40}P_{20}$	104	250	82,5	305,6
with irrigation water: in the phase of 10-12 leaves $N_{60}P_{30}$; in the phase of discharging the $N_{60}P_{30}$; in the phase of milk ripeness of grain $N_{60}P_{30}$;	103	240	83,5	318,4
with irrigation water: in the phase of 10-12 leaves of $N_{90}P_{45}$ and in the phase of discharging of the $N_{90}P_{45}$.	103	270	82,8	335,8

The weight of 1000 grains was maximum – 335.8 g at the dose of $N_{90}P_{45}$ in two terms (in the phase of 10-12 throwing leaves and panicles). It was minimal in areas where fertilizers were not used.

The differences in the average weight of the cabbage are determined (Table 3). The largest weight of the cabbage – 270 grams is also marked when applying mineral fertilizers in two terms (in the phase of 10-12 throwing leaves and panicles).

In comparison with the traditional technology of introducing mineral fertilizers for fertigation, the weight of a single chamfer increased from 5 to 45 g.

The introduction of rubbish in the market with irrigation water compared to a one-time application of them increased the yield of grain by 1.9-2.9 % (except for the introduction of mineral fertilizers in two terms – on $N_{60}P_{30}$ and $N_{120}P_{60}$).

Fertigation at different times created favorable conditions for the growth and development of corn plants. Its positive effect was noted on the increase in the mass of 1000 grains, the average weight of the swathes and the yield of corn grain.

The yield of grain of the hybrid Pioneer 3978 for the application of mineral fertilizers with irrigation water was higher than the traditional technology of their introduction (Table 4). A stable increase in yield was obtained when introducing liquid complex fertilizers with irrigation water.

Table 4. Influence of methods and terms of mineral fertilizers on the grain yield of the hybrid Pioneer 3978, t/ha

Variant	Year 2002	Year 2003	Year 2004	Average for three years
No fertilizer (control)	3,7	3,6	4,2	3,8
N_{180} P_{90} (urea + ammophos) in the spring for cultivation	9.9	8,2	9,7	9,3
$N_{180}P_{90}$ under cultivation before sowing (urea + LCF) with irrigation water	9,6	8,4	9,8	9,3
with irrigation water $N_{60}P_{30}$ after sowing and $N_{120}P_{60}$ in the phase of 10-12 leaves	10,0	8,7	10,1	9,6
with irrigation water: after sowing $N_{50}P_{25}$; in the phase of 10-12 leaves of $N_{50}P_{25}$ in the phase of discharging the vagrants $N_{40}P_{20}$; in the phase of milk ripeness of grain $N_{40}P_{20}$	10,9	8,7	10,1	9,9
with irrigation water: in the phase of 10-12 leaves $N_{60}P_{30}$; in the phase of discharging the $N_{60}P_{30}$; in the phase of milk ripeness of grain $N_{60}P_{30}$;	11,0	8,7	10,3	10,0
with irrigation water: in the phase of 10-12 leaves of $N_{90}P_{45}$ and in the phase of discharging of the $N_{90}P_{45}$.	11,6	9,2	10,5	10,4

The maximum yield of maize grain, on average, over three years, was obtained for the application of $N_{90}P_{45}$ with irrigation water in the phase of 10-12 leaves and in the phase of evacuation of molasses – 10.4 t/ha. The fertilizer dose of $N_{180}P_{90}$ bestowed itself on the increase in yields for making it twice in equal parts in the phases of 10-12 leaves and discharging the vagrants (according to $N_{90}P_{45}$).

The study of the efficiency of the use of liquid complex fertilizers in the system of intensive technology of corn cultivation on grain under irrigation conditions should be continued, taking into account the varietal differences and biotypes of cultivated hybrids, as well as periods of maximum consumption of soil moisture and nutrients.

Conclusions

According to the results of the research carried out in 2002-2004 in the conditions of the northern Steppe of Ukraine, high efficiency of minimization of soil cultivation and fertilizing irrigation (fertigation) on black crops common in the production of corn grain on irrigated lands was established. Modern methodological approaches to the phased evaluation of the entire technological cycle of corn grain yield and practical experience indicate that there are significant reserves available for reducing the energy intensity of this crop.

The minimization of soil cultivation, the introduction of irrigation water of chemicals, the use of resource-saving and environmentally safe cropping, irrigation, harvesting and transport vehicles will reduce the energy costs of corn grain production by irrigation by at least 35-40 %, thus transforming an intensive energy-intensive cultivation technology into energy saving. Realized the unique possibility of synchronous optimization of the water regime of plants and the provision of their easily accessible forms of nutrients at the stages of organogenesis.

Application of the proposed agrotechnology will allow to obtain high yields of corn grain under irrigation conditions for the optimal combination of agronomic techniques with the rational use of irrigation water, mineral fertilizers, energy and material resources.

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