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05.00.00 — Texnika fanlari
06.00.00 — Qishloq xo‘jaligi fanlari
08.00.00 — Iqtisodiyot fanlari

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ANALYSIS AND MATHEMATICAL MODELING OF ENERGY CONSUMPTION OF LINTERING MACHINES IN COTTON GRINDING ENTERPRISES

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Abstract. *Estimation of energy consumption in the processing of cotton raw materials in a linter, determination of the laws of change of electrical loads and relative energy consumption and the most convenient modes. Also, it is important to correctly determine the installed power of electric drives of linter machines and determine the required power on the shaft of their engines, and to analyze the energy performance of the enterprise and workshops.*

Keywords. *linter of cotton ginning enterprises, the intensity of the supply of cotton to the linter, the total installed capacity of linters, the efficiency of the linter, the relative energy consumption of the linter.*

Annotatsiya. *Paxta xomashyosini linterda qayta ishlashda energiya sarfini baholash, elektr yuklamalarining o'zgarish qonuniyatlari va nisbiy energiya sarfi hamda eng qulay rejimlarni aniqlash. Shuningdek, linter mashinalari elektr yuritmalarining o'rnatilgan quvvatini to'g'ri aniqlash va ularning dvigatellari validagi zarur quvvatni belgilash, hamda korxona va sexlarning energetik ko'rsatkichlarini tahlil qilish muhim ahamiyatga ega.*

Kalit so'zlar. *Paxta tozalash korxonalari linteri, linterga paxta berish intensivligi, linterlarning umumiy o'rnatilgan quvvati, linterning foydali ish koeffitsienti, linterning nisbiy energiya sarfi.*

Аннотация. *Оценка энергопотребления при переработке хлопкового сырья в линтере, определение закономерностей изменения электрических нагрузок и относительного энергопотребления, а также наиболее удобных режимов. Также важно правильно определить установленную мощность электроприводов линтерных машин и определить требуемую мощность на валу их двигателей, а также проанализировать энергетические показатели предприятия и цехов.*

Ключевые слова. *линтер хлопкоочистительных предприятий, интенсивность подачи хлопка в линтер, общая установленная мощность линтеров, коэффициент полезного действия линтера, относительное энергопотребление линтера.*

INTRODUCTION

In the world, scientific and research work is being carried out aimed at developing new scientific and technical solutions for improving cotton processing and

product quality, optimizing technological equipment and operating modes using energy-efficient technologies. In this regard, taking into account the fact that cotton processing is mainly seasonal, special attention is paid to increasing the operational efficiency of electrical equipment used in the implementation of processes and thereby achieving energy efficiency in the industry.

The purpose of the study is to develop scientific foundations for increasing the energy efficiency of technological devices at the stage of processing cotton raw materials, taking into account the characteristics of cotton varieties, taking into account the characteristics of cotton varieties, while preserving the natural qualities of fibers and seeds.

MATERIALS AND METHODS

To analyze the main technologies for estimating energy consumption in the processing of cotton raw materials, probability theory and mathematical statistics, mathematical analysis, the principal components method, and correlation-regression methods were used.

RESULTS AND DISCUSSION

Cotton seed linting processes Cotton seed linting processes are carried out at cotton ginning plants. The linting process is carried out in order to separate this lint from the seed composition. Linting of cotton in cotton ginning plants is carried out in saw linters, which undergo various levels of intensive processing.

Depending on the need to obtain one or another type of lint, the following linting technologies can be used - the first two-stage enhanced lint removal, the second two-stage enhanced lint removal and the third stage lint removal. These processes are carried out by the PMP-160M linter machine with the UPML working chamber, 5LP and 6LP linters and units with the help of saw teeth and strong air separation.

In saw linters, the linting process is based on the mechanical action of rotating roller saws with the grain, as a result of which the teeth scrape off the fiber (lint) from the surface of the grain removed from the saw, which is sent to the condenser by air.

The main indicators of linter performance are: the amount of lint removed from the grain and the degree of lint exit from the grain, and the linter efficiency is calculated. Depending on the selected linting technology and the need to produce the required type of lint, taking into account the control of the linter operation, the appropriate lint removal for each type of lint is studied experimentally by adjusting the linter efficiency.

A comprehensive study of the linting process requires the disclosure of a number of factors, the main indicators of which are the productivity, the degree of lint removal and its quality:

seed selection, industrial grade and fineness of the fiber in the seed (the amount of fluff); linting mode; the condition of the saws and their diameter; the parameters of the linter working chamber and its working bodies, and the speed modes of the mixer and saw cylinder.

The effect of cotton selection and industrial grades on the productivity of linting machines and linting quality is determined, in particular, by a significant difference in the linting indicators of the seed after ginning.

Depending on the need to obtain a particular assortment of lint, the appropriate linting technology is selected. To obtain a full range of lint, it is necessary to undergo a three-stage linting technology, first by removing 2%, secondly by removing up to 4%, and thirdly by removing 2% or more. Double linting ensures maximum output of the second type of lint by removing the first reinforced lint (up to 6%), and the second linting (with 2% removal) produces the third type of lint.

During the first linting process, lint removal exceeding 6% leads to a significant unevenness of the produced lint along the length, which is related to the third type, as well as to an increase in its clogging. The technology of double linting with an increased secondary removal leads to an increase in the first type 1 lint (removal up to 2%) and an increase in the second type 3 lint with a lint removal of 6% or more [20; pp. 52-67].

During the first linting, the condition of the working chamber of the machine and the mixer in it significantly affects the work efficiency. The condition of the chamber and the mixer in it, the gap between the mixer grates and the saws, the protrusion of the saws and the pitch of the saw teeth have the most important effects on lint removal.

Experimental studies of the first and second linting processes have shown that it is necessary to calculate the equations related to the work efficiency (while maintaining a certain lint removal) taking into account the 3 most important factors - the position of the working chamber relative to the saw cylinder, the speed of the mixer and the saw:

1st linting (2% lint removal):

$$A_1 = 1121 + 1{,}2n_{пц} + 15{,}7\alpha - 0{,}1n_{пц}\alpha + 0{,}2n_B\alpha, \text{ kg/h} \quad (1)$$

2nd linter (4% lint removed)

$$A_2 = 2431 - 1{,}5n_{пц} - 4{,}4n_B + 65{,}7\alpha + 0{,}006n_{пц}n_B - 0{,}006n_{пц} \text{ kg/h} \quad (2)$$

where - A_1, A_2 the efficiency of the saw linter in the first and second linting of seeds, kg/h;

$n_{пц}, n_B$ - rotation speed of the saw cylinder and mixer, rpm;

α - the angle of rotation of the working chamber relative to the cylinder (5 LP from the main position in the linter), grad.

The values of the following factors in the experimental field $n_{пц} = 630$, $n_ц = 830{,}400$, $n_B = 600$ the adequacy of the equations for; $\alpha = 10°$.

While maintaining the state of the working chamber, as in the 5LP linter, the equations are simplified and take the following form:

1st linter (linting removal - 2%):

$$A_1 = -301 + 1{,}2n_{пц} + 3{,}2n_B \text{ kg/h} \quad (3)$$

2-Lintering (Linter removal - 4%):

$$A_2 = 2431 - 1{,}5n_{пц} - 4{,}4n_B + 0{,}006n_{пц}n_B \text{ kg/h} \quad (4)$$

Based on the data provided and the calculations obtained from the equations, it is possible to select linter technology and its modes in order to increase the efficiency of lint production at cotton ginning enterprises.

Saw linter machines PMP-160M can replace low-performance linters with 5LP linter machines and ensure the production of products with high quality indicators. The main difference between the 5LP linter and the PMP-160 linter is the enlarged working grain chamber. Adjusting the linting process with a grain comb changes the lint output from the grain and the machine's productivity. With an increase in the distance between the grain comb and the grid, the removal of hairs from the grain decreases and at the same time the grain throughput increases.

After setting a certain gap between the grain comb and the grid, it is possible to increase the productivity of the linter by using an automatic control system, taking into account the optimal density of the grain in the working chamber along a certain length of the lint production.

The pulse variator is designed to automatically control the supply of grain to the working chamber of the linter by changing the rotation speed of the supply drum depending on the change in the density of the grain in the grain roller. The intensity of the supply of grain to the linter, its productivity, is established experimentally, taking into account the required density of the grain roller.

The change in the position of the load on the handle of the valve density and its weight affects the density of the grain roller and the productivity of the linter. The constant load of the linter machine itself increases the productivity of the grain linter and vice versa. Increasing the density at the valve stem is usually used when a small change in the linter's grain supply is required.

Depending on the design of the linters, saws with a diameter of 320, 310, 300 and 290 mm are used. To facilitate the process of installing new or roller saws on the linters, it is recommended to try using one or another linter with a constant diameter. When installing saws of other diameters on the linter, the position of the air chamber and the grate is adjusted.

The output of the saws above the grate is carried out by adjusting the support bolts of the shaft under the grate and the suspension mechanism of the linter's working chamber. The separation of sawdust and foreign impurities from the lint is regulated by means of a sawdust cover that can be moved towards or away from the saw. Since the sawdust is processed in three linting operations in sawdust linters after collection, we experimentally determined the energy consumption of each lint output and the actual average work efficiency.

Mathematical models of energy consumption characteristics of PMP-160, PMP-160m and 5LP saw linters are expressed as follows:

For PMP-160 and 160M: for first output

$$P'_{ПМП} = 25{,}3 + 0{,}0018\,A'_{ПМП} \text{ kWt;} \quad (5)$$

$$d'_{ПМП} = \frac{25{,}3}{A'_{5ЛП}} + 0{,}0018 \quad \text{kWt·h/kg.} \quad (6)$$

for the second exit

$$P''_{ПМП} = 25{,}3 + 0{,}0021\,A''_{ПМП} \text{ kWt;} \quad (7)$$

$$d''_{ПМП} = \frac{25{,}3}{A''_{ПМП}} + 0{,}0021 \text{ kWt·h/kg} \quad (8)$$

for the third exit

$$P'''_{ПМП} = 25{,}3 + 0{,}0028\,A'''_{ПМП}, \quad \text{kWt;} \quad (9)$$

$$d'''_{ПМП} = \frac{25{,}3}{A'''_{5.ЛП}} + 0{,}0028 \quad \text{kWt·h/kg} \quad (10)$$

For 5 LP brand saw linters: for first release

$$P'_{5.ЛП} = 24{,}8 + 0{,}0016\,A'_{5.ЛП} \quad \text{kWt;} \quad (11)$$

$$d'_{5.ЛП} = \frac{24{,}8}{A'_{5.ЛП}} + 0{,}0016 \quad \text{kWt·h/kg.} \quad (12)$$

for the second exit

$$P''_{5.ЛП} = 24{,}8 + 0{,}0022\,A''_{5.ЛП} \quad \text{kWt;} \quad (13)$$

$$d''_{5.ЛП} = \frac{24{,}8}{A''_{5.ЛП}} + 0{,}0022 \quad \text{kWt·h/kg.} \quad (14)$$

for the third exit

$$P'''_{5.ЛП} = 24{,}8 + 0{,}0027\,A'''_{5.ЛП} \quad \text{kWt;} \quad (15)$$

$$d'''_{5.ЛП} = \frac{24{,}8}{A'''_{5.ЛП}} + 0{,}0027 \quad \text{kWt·h/kg.} \quad (16)$$

The useful composition and load losses of saw linters during nominal operation do not exceed 5-8% of the energy consumption.

From expressions (15) and (16) it can be seen that the average energy consumption of saw linters does not depend on the productivity, and this characteristic can be considered universal and describes the laws of changing the power consumption and relative energy consumption for fibers of different lengths produced by a saw linter.

The 6 LP linter machine is produced in 2 types according to its operating function: 6 LP and LP-1 are designed to perform two-time final linting of the grain in one machine, and the linting process is carried out in the same way as in saw linters of the PMP-160M and 5 LP brands. The 6 LP linter machine has two section saw cylinders, each with 160 saws.

6 The LP-01 linter machine also has two section saw cylinders, each with 100 and 160 saws, which provide 6% yield of first and second type lints. One of the main indicators of the machine is the high output level of lint from the upper and lower linting sections, that is, high productivity.

During linting, the feeder is adjusted in the lower section of the working chamber of the machine depending on the volume of grain on the roller. To increase the efficiency of the machine, the density valve in the lower linting section of the working chamber is adjusted by changing the lever connecting the variator with the density valve, as well as moving the load to the handle of the density valve.

The operating mode lasts a long time with a constant load. The total installed capacity and the efficiency of the 5LP PMP-160M UMPL chamber saw linters in terms of grain can be seen in Table 1.

Table 1

Mathematical models of the energy consumption characteristics of the PMP-160, PMP-160m and 5LP saw linters

№	sawn brand of linters	Installed capacity, kWt	Seed productivity, kg/h	Comparative energy consumption, kWt·h/kg
1.	PMP-160 PMP-160M	31,2	In the first release of fiber 2000	$d'_{ПМП} = 0{,}0156$
			in his second appearance 1700	$d''_{ПМП} = 0{,}0184$
			on his third appearance 1300	$d'''_{ПМП} = 0{,}024$
2.	5LP	30,6	In the first release of fiber 2300	$d'_{5LP} = 0{,}0133$
			in his second appearance 1700	$d''_{5ЛП} = 0{,}018$
			on his third appearance 1360	$d'''_{5ЛП} = 0{,}0225$

In each of the linting sections, the necessary lint is removed using lint combs, similar to the 5LP brand of sawn linters. The removal of hairs and impurities from the lint is carried out by adjusting the air chamber covers of the upper section.

Synchronization of the operation of the upper and lower linting sections in the set modes, as well as ensuring their stable operation, is carried out by moving the lever columns connecting the density valve of the lower section with the variator.

When starting the linter at high load, the upper column of the upper section should be lowered. To accelerate the filling of the upper section with lint, the column of the lower section should be raised. The installed power of the 6LP brand linter machine is 61.2 kWt. The linter's working efficiency is 88 kg/h for lint and 1180 kg/h for lint. The planned value of the relative energy consumption of the linter is 695 kWt·h/t for lint and 52 kWt·h/t for sawdust.

Formulas have been developed to calculate the power consumption and relative energy consumption depending on the performance of the linter.

$$P_{6ЛП} = 44 + 0{,}009\,A_{6ЛП}\,, \quad \text{kWt} \qquad (17)$$

$$d_{6ЛП} = \frac{44}{A_{6ЛП}} + 0{,}009\,, \quad \text{kWt·h/kg} \qquad (18)$$

In accordance with expressions (17) and (18), the normative energy characteristics of the power consumption and relative energy consumption of the 6LP linter machine are constructed.

The study of the electrical load modes of the main machines and mechanisms of the cotton ginning industry showed that:

- assessment of the energy consumption of all varieties of cotton raw materials processed in each cotton ginning and linting machine according to their design features and production technology;

- determination of the laws of change and the most favorable modes of electrical loads and relative energy consumption for saw and roller gins, as well as linters. Determines the directions for reducing inefficient energy costs by reducing the maximum electrical loads at the enterprise, reducing the costs of traditional commissioning;

- development of a reliable empirical formula that allows to correctly determine the installed power of electric drives of jin-linter machines and to determine the necessary power falling on the shaft of the engine;

- the need to create a base for analyzing and predicting the energy indicators of the enterprise and shops as a whole was justified.

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ПАХТА ТОЗАЛАШ КОРХОНАЛАРИДА ЛИНТЕРЛАШ МАШИНАЛАРИНИНГ ЭНЕРГИЯ ИСТЕЪМОЛИНИ ТАҲЛИЛ ҚИЛИШ ВА МАТЕМАТИК МОДЕЛЛАШТИРИШ

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Аннотация. *Линтерлаш машинасида пахта хом ашёсини қайта ишлашда энергия сарфини баҳолаш, электр юклари ва солиштирма энергия сарфини ўзгариш қонуниятларини ва энг қулай режимларини белгилаш. Шунингдек, линтер машиналари электр юритмаларининг ўрнатилган қувватини тўғри белгилаш ва двигателининг валига тушадиган зарур қувватни аниқлаш, корхонанинг ва цехларнинг энергетик кўрсаткичларини таҳлил қилишда долзарб ҳисобланади.*

Калит сўзлар. *пахта тозалаш корхоналарида чигитларни линтерлаш, линтерга чигитни етказиб беришнинг интенсивлик даражаси, линтерларининг умумий ўрнатилган қуввати, линтернинг иш унумдорлиги, линтернинг солиштирма энергия сарфи.*

Аннотация. *Оценка энергопотребления при переработке хлопкового сырья на линтерной машине, определение закономерностей изменения электрических нагрузок и удельного энергопотребления, а также наиболее оптимальных режимов работы. Кроме того, актуальным является правильное определение установленной мощности электроприводов линтерных машин и расчёт необходимой мощности на валу их двигателей, а также анализ энергетических показателей предприятия и цехов.*

Ключевые слова. *линтерование семян на хлопкоочистительных предприятиях, интенсивность подачи семян в линтер, общая установленная мощность линтеров, производительность линтера, удельное энергопотребление линтера.*

Abstract. *Estimation of energy consumption in the processing of cotton raw materials in a linter, determination of the laws of change of electrical loads and relative energy consumption and the most convenient modes. Also, it is important to correctly determine the installed power of electric drives of linter machines and determine the required power on the shaft of their engines, and to analyze the energy performance of the enterprise and workshops.*

Keywords. *linter of cotton ginning enterprises, the intensity of the supply of cotton to the linter, the total installed capacity of linters, the efficiency of the linter, the relative energy consumption of the linter.*

КИРИШ

Жаҳонда пахтани қайта ишлаш ва маҳсулот сифатини ошириш, энергия тежамкор технологиялардан фойдаланишда технологик ускуналарни мақбул бошқариш ва иш режимларини оптималлаштиришнинг янги илмий-техникавий ечимларини ишлаб чиқишга йўналтирилган илмий-тадқиқот ишлари олиб борилмоқда. Бу борада, жумладан пахтани қайта ишлаш асосан мавсумий харакатларга эга бўлганлигини инобатга олган ҳолда жараёнларни амалга оширишда фойдаланилаётган электротехник ускуналарни эксплуатацион самарадорлигини ошириш ва бу орқали соҳада энергия тежамкорликка эришишга алоҳида эътибор берилмоқда.

Тадқиқотнинг мақсади пахта хом ашёсини қайта ишлашнинг мавжуд технологик жараёнларини таҳлил қилиш асосида, пахта сортлари кўрсаткичларининг хусусиятларини ҳисобга олган ҳолда, пахта хом ашёсига ишлов бериш босқичида - тола ва чигитларнинг табиий сифатларини сақлаш орқали, технологик қурилмаларни энергия самарадорлигини оширишнинг илмий асосларини ишлаб чиқишдан иборат.

МАТЕРИАЛЛАР ВА УСУЛЛАР

Пахта хом ашёсини қайта ишлашда энергия сарфини баҳолаш учун асосий технологияларини таҳлил қилиш учун эҳтимоллар назарияси ва математик статистика, математик таҳлил, бош компонентлар услуби, корреляция-регрессия усулларидан фойдаланилган.

НАТИЖАЛАР ВА МУҲОКАМА

Пахта чигитини линтерлаш жараёнлари пахта тозалаш корхоналарида пахтани жинлаш жараёнидан ишлаб чиқарилган чигит таркибида жинланган пахтанинг селекцион навини инобатга олган ҳолда ўртача 10-15% миқдорида момиқ бўлади. Ушбу момиқни чигит таркибидан ажратиб олиш учун чигитни линтерлаш жараёни амалга оширилади. Пахта тозалаш корхоналарида чигитларни линтерлаш турли даражадаги интенсив қайта ишлаш жараёнларидан ўтувчи аррали линтерларида амалга оширилади.

У ёки бу бошқа турдаги линтларни олиш зарурлигига қараб, қуйидаги чигитларни линтерлаш технологиялари қўлланилиши мумкин – биринчи икки даражалик кучайтирилган ҳолда линтни олиб ташлаш, иккинчи икки даражалик кучайтирилган линтни олиб ташлаш ва учинчи даражалик линтни олиш жараёнларидан ўтади. Ушбу жараёнлар ПМП-160М маркали линтер машинаси УПМЛ ишчи камераси билан, 5ЛП ва 6ЛП маркали линтерлар ва агрегатлари орқали арра тишлари билан кучли ҳаво орқали ажратиб олинади.

Аррали линтерларда линтлаш жараёни чигит билан айланувчи валик арраларнинг механик таъсирига асосланади, бунинг натижасида тишлар аррадан олинадиган чигитлар юзасидан толани (линтни) кириб ташлайди, ҳаво орқали конденсаторга юборилади.

Линтер ишлашининг асосий кўрсаткичлари қуйидагилардир: чигитлар-дан линтларни олиб ташлаш миқдори ва линтнинг чигитдан чиқиш даражаси ва линтнинг иш унумдорлиги хисобланади.

Танланган линтерлаш технологиясига ва керакли турдаги линтлар ишлаб чиқариш зарурлигига қараб, линтернинг ишлаши назорат қилинишини ҳисобга олган ҳолда, ҳар бир турдаги линт учун тегишли линтлар олиб ташлашни линтернинг иш унумдорлигини ростлаш орқали тажрибалар ёрдамида тадқиқ қилинади.

Линтерлаш жараёнини комплекс тадқиқ қилишда бир қатор омилларни очиб бериш талаб этилади, линтерлаш жараёнига асосий кўрсаткичларига таъсир қилувчи - унумдорлик, линтлар олиб ташлаш даражаси ва унинг сифати:

чигитнинг селекцияси, саноат сорти ва чигитдаги толанинг барралиги (туклар миқдори); линтерлаш режими; арраларнинг ҳолати ва уларнинг диаметри; линтернинг иш камераси ва унинг ишчи органлари параметрлари ва аралаштиргич ва арра цилиндрининг тезлик режимлари ҳисобланади.

Пахтанинг селекцияси ва саноат сортларининг линтер машинларининг иш унумдорлигига ва линтлаш сифатига таъсири, айниқса, жинлашдан кейин чигитнинг линтлилик кўрсаткичларидаги сезиларли фарқ билан аниқланади.

Линтларнинг у ёки бошқа ассортиментини олиш зарурлигига қараб, тегишли линтерлаш технологияси танланади. Тўлиқ ассортиментдаги линтни олиш учун уч марталик линтер технологиясидан ўтиши керак, биринчида 2%, иккинчисида 4% гача ва учинчида 2% ва ундан кўпроқ узиб олиш орқали олинади. Икки марта линтлаш биринчи кучайтирилган линтларни олиб ташлаш (6% гача) иккинчи турдаги линтнинг максимал чиқишини таъминлайди ва иккинчи линтерлашда (2% олиб ташлаш билан) учинчи турдаги линтлар ишлаб чиқилади.

Биринчи линтерлаш жараёнида линтлар олиб ташлашнинг 6% дан ошиши учинчи турга тегишли бўлган узунлик бўйлаб ишлаб чиқарилган линтнинг сезиларли даражада нотекислигига, шунингдек, унинг тиқилиб қолишининг кучайишига олиб келади. Кучайтирилган иккинчи даражали олиш билан икки марталик линтерлаш технологияси биринчи 1 турдаги линтнинг ошишига (2% гача олиб ташлаш) ва иккинчи линтерда 6% ёки ундан кўп линтерлашда 3 турдаги линтнинг ошишига олиб келади [20; 52-67-б.].

Биринчи линтерлаш пайтида машинанинг ишчи камераси ва ундаги аралаштиргичнинг ҳолати иш унумдорлигига сезиларли таъсир қилади. Линтни олиб ташлашда камера ва ундаги аралаштиргичнинг ҳолати, аралаштиргич панжаралари ва арралар оралиғи, арраларнинг чиқиб кетиши ва арра тишларининг қадами энг муҳим таъсир кўрсатади.

Биринчи ва иккинчи линтерлаш жараёнларининг тажриба тадқиқотлари шу кўрсатдики, 3 та энг муҳим омилни - иш камерасининг арра цилиндрига нисбатан ҳолатини, аралаштиргич ва арра айланиш тезлигини ҳисобга олган ҳолда иш унумдорлиги билан боғлиқ тенгламаларни ҳисоблашга тўғри келади (маълум бир линтлар олиб ташлашни сақлаб турганда):

1-линтерлаш (2% линтлар олиб ташланиши):

$$A_1 = 1121 + 1{,}2n_{пц} + 15{,}7\alpha - 0{,}1n_{пц}\alpha + 0{,}2n_B\alpha, \text{ kg/h} \quad (1)$$

2-линтерлаш (4% линтлар олиб ташланади)

$$A_2 = 2431 - 1{,}5n_{пц} - 4{,}4n_B + 65{,}7\alpha + 0{,}006n_{пц}n_B - 0{,}006n_{пц} \quad \text{kg/h} \quad (2)$$

бунда A_1, A_2 -чигитларни биринчи ва иккинчи линтерлашда аррали линтернинг иш унумдорлиги, kg/h;

$n_{пц}, n_B$ - аррали цилиндр ва аралаштиргичнинг айланиш тезлиги, rpm;

α - ишчи камерасининг цилиндрга нисбатан бурилиш бурчаги (5 ЛП линтердаги асосий ҳолатидан), град.

Тажриба майдонда қуйидаги омиллар қийматлари $n_{пц} = 630$, $n_ц = 830{,}400$, $n_B = 600$ учун тенгламаларнинг адекватлиги таъминланади; $\alpha = 10°$.

Ишчи камерасининг ҳолатини сақлаб турганда, 5ЛП линтерида бўлгани каби, тенгламалар соддалаштирилади ва қуйидаги шаклга эга бўлади:

1-линтерлаш (линтингни олиб ташлаш - 2%):

$$A_1 = -301 + 1{,}2n_{пц} + 3{,}2n_B \quad \text{kg/h} \quad (3)$$

2-линтерлаш (линтерни олиб ташлаш - 4%):

$$A_2 = 2431 - 1{,}5n_{пц} - 4{,}4n_B + 0{,}006n_{пц}n_B \quad \text{kg/h} \quad (4)$$

Келтирилган маълумотларга асосан ва тенгламалардан олинган ҳисобга кўра пахта тозалаш корхоналарида линт ишлаб чиқариш самарадорлигини ошириш мақсадида линтер технологияси ва унинг режимларини танлаш мумкин.

Аррали линтер машиналари ПМП-160М маркали иш унумдорлиги паст линтерларни 5ЛП маркали линтер машиналарига алмаштириш мумкин ва сифатли кўрсаткичларга эга маҳсулотлар ишлаб чиқаришни таъминлайди. 5ЛП маркали линтернинг ва ПМП-160 линтер ўртасидаги асосий фарқ кенгайтирилган ишчи чигитлик камераси ҳисобланади. Линтерлаш жараёнини чигитлик тароқ ёрдамида ростлаш чигитдан линтнинг чиқиши ва машинанинг иш унумдорлигини ўзгартиради. Чигитлик тароқ ва панжара оралиғининг ошиши билан чигитларда туклар олиб ташланиши камаяди ва бир вақтнинг ўзида чигит ўтиши ортади.

Чигитлик тароғи ва панжара ўртасида маълум оралиқ ўрнатилгандан кейин линт ишлаб чиқаришнинг маълум бир узунлиги бўйича чигитнинг ишчи камерадаги валикдаги оптимал зичлигини ҳисобга олган ҳолда автоматик бошқарув тизими ёрдамида иш унумдорлигини ошириш мумкин.

Импулсли вариатор-чигитлик валикдаги зичлигининг ўзгаришига қараб, таъминлагич барабанининг айланиш тезлигини ўзгартириш орқали линтернинг иш камерасига чигитларни етказиб берилишини автоматик равишда бошқариш учун мўлжалланган. Линтерга чигитни етказиб беришнинг интенсивлик даражаси, унинг иш унумдорлиги чигитлик валигининг керакли зичлигини ҳисобга олган ҳолда тажриба орқали ўрнатилади.

Клапан зичлигининг дастагдаги юкнинг ўрнини ва унинг оғирлигининг ўзгариши чигитлик валигининг зичлигига ва линтернинг иш унумдорлигига

таъсир қилади. Линтер машинасининг ўзининг доимий иш билан юкланиши чигитлик линтернинг иш унумдорлиги ошади ва аксинча. Клапан дастагидаги зичликнинг ошиши одатда линтернинг чигитлик таъминотини кичик ўзгартириш керак бўлганда қўлланилади.

Линтерларнинг конструкциясига кўра диаметри 320, 310, 300 ва 290 mm бўлган арралардан фойдаланилади. Цилиндрларни янги ёки роликли арралар билан ўрнатиш жараёнини енгиллаштириш учун линтерларда доимий диаметрли у ёки бу линтердан фойдаланишни синаб кўриш тавсия этилади. Бошқа диаметрли арраларни линтерга ўрнатишда ҳаво камераси ва панжаранинг ҳолати ростланади.

Арраларнинг панжара устидаги чиқиши панжара остидаги ўқнинг таянч болтларини ва линтернинг иш камерасининг осма механизмини ростлаш орқали амалга оширилади. Линтдан улюк ва бегона аралашмаларни ажратиш арра томон ёки ундан узоқлашиш қобилиятига эга бўлган улюк қопқоғи ёрдамида тартибга солинади. Жинлашдан кейин аррали линтерларда чигит уч марта линт чиқаришда қайта ишланиши сабабли биз ҳар бир линт чиқишининг энергия сарфини ва ҳақиқий ўртача иш унумдорлигини тажриба йўли билан аниқланди.

ПМП-160, ПМП-160м ва 5ЛП маркали аррали линтерларнинг энергия истеъмол қилишнинг энергетик характеристикаларини математик моделлари қуйидагича ифодаланади:

ПМП-160 ва 160М учун: биринчи чиқиш учун

$$P'_{ПМП} = 25{,}3 + 0{,}0018\,A'_{ПМП}\ \text{kWt};\ (5)$$

$$d'_{ПМП} = \frac{25{,}3}{A'_{5ЛП}} + 0{,}0018\quad \text{kWt·h/kg.}\ (6)$$

иккинчи чиқиш учун

$$P''_{ПМП} = 25{,}3 + 0{,}0021\,A''_{ПМП}\ \text{kWt};\quad (7)$$

$$d''_{ПМП} = \frac{25{,}3}{A''_{ПМП}} + 0{,}0021\ \text{kWt·h/kg}\ (8)$$

учинчи чиқиш учун

$$P'''_{ПМП} = 25{,}3 + 0{,}0028\,A'''_{ПМП},\quad \text{kWt};\ (9)$$

$$d'''_{ПМП} = \frac{25{,}3}{A'''_{5ЛП}} + 0{,}0028\ \text{kWt·h/kg}\ (10)$$

5 ЛП маркали аррали линтерлар учун: биринчи чиқиш учун

$$P'_{5ЛП} = 24{,}8 + 0{,}0016\,A'_{5ЛП}\ \text{kWt};\quad (11)$$

$$d'_{5ЛП} = \frac{24{,}8}{A'_{5ЛП}} + 0{,}0016\quad \text{kWt·h/kg.}\ (12)$$

иккинчи чиқиш учун

$$P''_{5ЛП} = 24{,}8 + 0{,}0022\,A''_{5ЛП}\ \text{kWt};\ (13)$$

$$d''_{5ЛП} = \frac{24,8}{A''_{5ЛП}} + 0,0022 \quad \text{kWt·h/kg. (14)}$$

учинчи чиқиш учун

$$P'''_{5ЛП} = 24,8 + 0,0027\, A'''_{5ЛП} \ \text{kWt}; \quad (15)$$

$$d'''_{5ЛП} = \frac{24,8}{A'''_{5ЛП}} + 0,0027 \ \text{kWt·h/kg. (16)}$$

Аррали линтерлар номинал ишлаганда фойдали таркиблари ва юк йўқотишлари энергия сарфининг 5÷8% дан ошмайди.

(15) ва (16) ифодадан кўриш мумкин арра линтерларининг ўртача энергия сарфи унумдорликка боғлиқ эмаслигини ва бу олинган характеристикани универсал деб ҳисоблаш мумкин ва аррали линтер томонидан ишлаб чиқарилган турли узунликдаги толалар учун қувват истеъмолини ва солиштирма энергия сарфини ўзгартириш қонуниятларини тавсифлайди.

6 ЛП маркали линтер машинаси ишлаш функциясига кўра 2 турда ишлаб чиқарилади: 6 ЛП ва ЛП-1 битта машинада чигитлардан икки марталик якуний линтерлашни амалга ошириш учун мўлжалланган бўлиб, линтерлаш жараёни ПМП-160М ва 5 ЛП маркали аррали линтерларда бўлгани каби амалга оширилади. 6 ЛП маркали линтер машинасида иккита секцияли аррали цилиндрлар бўлиб, ҳар бирида 160 та арралари мавжуд.

6 ЛП-01 маркали линтер машинасида хам иккита секцияли аррали цилиндрлар бўлиб, ҳар бирида 100 ва 160 тадан арралари мавжуд, улар биринчи ва иккинчи турдаги линтлар чиқишини 6% га таъминлайди. Юқори ва пастки линтерлаш секциясидан линтнинг чиқиш даражасининг юқорилиги, яъни иш унумдорлигини юқорилиги машинанинг асосий кўрсаткичларидан бири ҳисобланади.

Линтерлашда машинанинг ишчи камерасидаги пастки секциясида валикдаги чигитнинг хажмига қараб таъминлагич ростланади. Машинанинг иш унумдорлигини ошириш учун ишчи камерасидаги пастки линтерлаш секциясида зичлик клапанини вариатор билан боғлайдиган дастагни ўзгартириш, шунингдек юкни зичлик клапанининг дастагига силжитиш орқали ростланади.

Ишлаш режими доимий юк билан узоқ давом этади. 5ЛП маркали ПМП-160М УМПЛ камерали аррали линтерларининг умумий ўрнатилган қуввати ва чигитлар бўйича иш унумдорлигини 1-жадвалда кўриш мумкин.

1-жадвал

ПМП-160, ПМП-160м ва 5ЛП маркали аррали линтерларнинг энергия истеъмолЬнинг энергетик характеристикаларини математик моделлари

№	Аррали линтерлар маркаси	Ўрнатилган қуввати, kWt	Чигитлар бўйича иш унумдорлиги, kg/h	Солиштирма энергия сарфи, kWt·h/kg

1.	ПМП-160 ПМП-160М	31,2	Толанинг биринчи чиқишида 2000 иккинчи чиқишида 1700 учинчи чиқишида 1300	$d'_{ПМП} = 0{,}0156$ $d''_{ПМП} = 0{,}0184$ $d'''_{ПМП} = 0{,}024$
2.	5ЛП	30,6	Толанинг биринчи чиқишида 2300 иккинчи чиқишида 1700 учинчи чиқишида 1360	$d'_{5ЛП} = 0{,}0133$ $d''_{5ЛП} = 0{,}018$ $d'''_{5ЛП} = 0{,}0225$

Линтерлаш секцияларининг ҳар бирида керакли линтларни олиб ташлаш учун 5 ЛП маркали аррали линтерларга ўхшаб чигит тароқлари ёрдамида амалга оширилади. Чигитлардан олиб ташланган туклар, аралашмаларни чиқариб ташлаш юқори секциянинг ҳаво камераларининг қопқоғини ростлаш ёрдамида амалга оширилади.

Юқори ва пастки линтерлаш секцияларининг ўрнатилган режимларда ишлашини синхронлаштириш, шунингдек уларнинг ишини барқарор ҳолатда бўлишини таъминлаш учун пастки секциясининг зичлик клапанини вариатор билан боғлайдиган дастаг устунларини силжитиш орқали амалга оширилади.

Линтерни юқори юкланишда ишга туширишда юқори секциянинг юқориги устунини пастга тушириш керак. Юқори секцияни чигитлар билан тўлдиришни тезлаштириш учун пастки секциянинг устунини юқорига кўтариш керак. 6ЛП маркали линтер машинасининг ўрнатилган қуввати 61,2 kWt ни ташкил қилади. Линтернинг иш унумдорлиги линт учун 88 kg/h, чигитлик учун эса 1180 kg/h. Линтернинг солиштирма энергия сарфининг режалаштирилган қиймати линт учун 695 kWt·h/t, чигитлик учун эса 52 kWt·h/t ни ташкил қилади.

Линтернинг иш унумдорлигига боғлиқ қувват истеъмоли ва солиштирма энергия сарфи учун ҳисобланган формулалар ишлаб чиқилди.

$$P_{6ЛП} = 44 + 0{,}009\,A_{6ЛП}\,, \quad \text{kWt (17)}$$

$$d_{6ЛП} = \frac{44}{A_{6ЛП}} + 0{,}009\,, \quad \text{kWt·h/kg (18)}$$

(17) ва (18) ифодаларга мувофиқ, 6ЛП линтер машинасининг қувват истеъмоли ва солиштирма энергия сарфининг меъёрий энергетик характеристикалари қурилган.

Пахта тозалаш саноатининг асосий машина ва механизмларининг электр юкланиш режимларини тадқиқ қилиш шуни кўрсатдики:

- ҳар бир пахта тозалаш ва линтерлаш машинасида қайта ишланган пахта хом ашёсининг барча сортларини уларнинг конструктив хусусиятлари ва ишлаб чиқариш технологиясига кўра энергия сарфини баҳолаш;

- аррали ва роликли жин машиналари, шунингдек, линтерлар учун электр юклари ва солиштирма энергия сарфини ўзгариш қонуниятларини ва энг қулай режимларини белгилаш. Корхонада максимал электр юкларини камайтириш, салт ишга тушириш харажатларини камайтириш орқали самарасиз энергия харажатларини камайтириш йўналишларини белгилайди;

- жин-линтер машиналарининг электр юритмаларининг ўрнатилган қувватини тўғри белгилаш ва двигателнинг валига тушадиган зарур қувватни аниқлаш имконини берувчи ишончли эмпирик формулани ишлаб чиқиш;

- умуман корхонанинг ва цехларнинг энергетик кўрсаткичларини таҳлил қилиш ва башорат қилиш учун база яратиш зарурлиги асосланди.

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HEMISMAS: OLIY TA'LIMDA ONLAYN TESTLASH VA BAHOLASH JARAYONLARINI AVTOMATLASHTIRUVCHI VEB-PLATFORMA

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Annotatsiya: *Ushbu maqolada HEMISMAS — oliy ta'lim muassasalari uchun mo'ljallab ishlab chiqilgan onlayn testlash va baholash platformasining arxitekturasi, funksional imkoniyatlari hamda amaliy natijalari tahlil etilgan. Platforma Supabase (PostgreSQL asosidagi Backend-as-a-Service), sof HTML5/CSS3/JavaScript texnologiyalari va Netlify CDN infratuzilmasiga tayanib qurilgan bo'lib, uch rollik foydalanuvchi modeli (admin, o'qituvchi, talaba) asosida ishlaydi. HEMISMAS tizimida zamonaviy anti-cheating mexanizmlari (MediaPipe yuzni aniqlash, ovoz nazorati, geolokatsiya tekshiruvi), sun'iy intellekt asosidagi natija tahlili (Groq Llama-3), QR-kodli PDF sertifikatlar va ko'p tilli interfeys (o'zbek, rus, ingliz) mavjud. Tadqiqot natijalari shuni ko'rsatmoqdaki, platforma o'quv jarayonini avtomatlashtirish, ma'lumotlar xavfsizligini ta'minlash va baholash sifatini oshirish borasida samarali vosita bo'lishi mumkin.*

Kalit so'zlar: *onlayn testlash, oliy ta'lim, veb-platforma, anti-cheating, Supabase, HEMISMAS, baholash avtomatizatsiyasi, sun'iy intellekt.*

Аннотация: *В данной статье анализируется архитектура, функциональные возможности и практические результаты платформы HEMISMAS — системы онлайн-тестирования и оценки знаний, разработанной для высших учебных заведений. Платформа построена на основе Supabase (Backend-as-a-Service на базе PostgreSQL), технологий HTML5/CSS3/JavaScript и инфраструктуры Netlify CDN, функционирует по трёхролевой модели пользователей (администратор, преподаватель, студент). В HEMISMAS реализованы современные механизмы защиты от списывания (определение лица MediaPipe, контроль звука, проверка геолокации), аналитика на основе искусственного интеллекта (Groq Llama-3), PDF-сертификаты с QR-кодом и многоязычный интерфейс. Результаты исследования показывают, что платформа может эффективно автоматизировать учебный процесс, обеспечить безопасность данных и повысить качество оценивания.*

Ключевые слова: *онлайн-тестирование, высшее образование, веб-платформа, защита от списывания, Supabase, HEMISMAS, автоматизация оценивания, искусственный интеллект.*

Abstract: *This article analyzes the architecture, functional capabilities, and practical results of HEMISMAS — an online testing and assessment platform developed for higher education institutions. The platform is built on Supabase (PostgreSQL-based Backend-as-a-Service), HTML5/CSS3/JavaScript technologies, and Netlify CDN infrastructure, operating based on a three-role user model (admin, teacher, student). HEMISMAS incorporates modern anti-cheating mechanisms (MediaPipe face recognition, voice monitoring, geolocation verification), artificial intelligence-based analytics (Groq Llama-3), QR-coded PDF certificates, and a multilingual interface (Uzbek, Russian, English). The research results demonstrate that the platform can effectively automate the educational process, ensure data security, and improve assessment quality.*

Keywords: *online testing, higher education, web platform, anti-cheating, Supabase, HEMISMAS, assessment automation, artificial intelligence.*

KIRISH

Zamonaviy axborot jamiyatida oliy ta’lim muassasalari bilimlarni baholash jarayonini raqamlashtirish va avtomatlashtirish zaruratiga duch kelmoqda. COVID-19 pandemiyasi davrida masofaviy ta’lim tizimiga o‘tish zarurati, raqamli texnologiyalarning jadal rivojlanishi va talabalar sonining ortib borishi an’anaviy baholash usullarini yangilashni taqozo etadi. An’anaviy qog‘oz asosidagi testlar vaqt va resurs sarflash nuqtai nazaridan nosamarali bo‘lib, ularning obyektivligi ham ko‘pincha shubha ostida qoladi.

Xalqaro tadqiqotlar shuni ko‘rsatadiki, onlayn baholash tizimlari o‘quv jarayonining samaradorligini sezilarli darajada oshirishi, o‘qituvchilarning vaqt sarfini esa kamaytirishi mumkin. Biroq Markaziy Osiyo mamlakatlarida, xususan O‘zbekistonda, mahalliy ta’lim tizimining xususiyatlarini hisobga olgan holda ishlab chiqilgan platforma juda kam. Ko‘pchilik muassasalar Google Forms yoki Moodle kabi umumiy yechimlarga murojaat qilsa-da, ular o‘zbek ta’lim tizimining spetsifik ehtiyojlarini to‘liq qondira olmaydi.

Bu muammolarni hal etish maqsadida HEMISMAS (Master Abdullaev’s Support) platformasi yaratildi. HEMISMAS — Andijon davlat universiteti magistranti Abdullayev Javohirbek Zokirjon o‘g‘li tomonidan mustaqil tashabbus asosida ishlab chiqilgan veb-platforma bo‘lib, u o‘qituvchilarga test yaratish, ulashish va natijalarni kuzatish, talabalarga esa xavfsiz va nazorat ostidagi muhitda topshiriq bajarish imkonini beradi.

Tadqiqotning maqsadi — HEMISMAS platformasining arxitekturasi, qo‘llanilgan texnologiyalar va amaliy samaradorligini IMRAD tuzilmasi asosida ilmiy tahlil qilish hamda uni mavjud yechimlar bilan solishtirishdir.

MAVZUGA OID ADABIYOTLARNING TAHLILI

Onlayn baholash tizimlari sohasidagi tadqiqotlar so‘nggi o‘n yilda jadal sur’atda rivojlandi. Gamage va boshqalarning 2020 yilda e’lon qilingan tadqiqoti shuni ko‘rsatadiki, kompyuter asosidagi testlash (Computer-Based Testing, CBT) an’anaviy qog‘oz testlarga nisbatan bir qator afzalliklarga ega: darhol natija berish, xatolar minimallashtirilishi va ko‘p variantli savollarni avtomatik tekshirish imkoniyati.

Sun’iy intellektni ta’limga integratsiya qilish masalasi ham keng o‘rganilgan. Chen va boshqalarining 2022 yildagi tadqiqotida LLM (Large Language Models) asosidagi tizimlarning talabalar uchun shaxsiy tavsiyalar berishdagi samaradorligi o‘rganilib, bu yondashuv o‘quv motivatsiyasini oshirishga ijobiy ta’sir ko‘rsatishi aniqlangan.

Baholash jarayonidagi aldash (cheating) muammosi alohida tadqiqot sohasi sifatida ajralib chiqdi. Dawson va Sutherland-Smith (2019) onlayn imtihonlarda aldash darajasini o‘rganishgan va an’anaviy imtihonlarga nisbatan onlayn muhitda bu ko‘rsatkich yuqoriroq bo‘lishini aniqlashgan. Bu muammoni yechish uchun Cluskey va boshqalar proktering tizimlarini taklif etgan.

Mahalliy texnologiyalarni ta’limga tatbiq etish masalasida ham muhim ishlar amalga oshirilgan. O‘zbekistonda «Raqamli O‘zbekiston — 2030» strategiyasi doirasida ta’lim muassasalarini raqamlashtirish dasturlari amalga oshirilmoqda. HEMIS (Higher Education Management Information System) tizimi oliy ta’lim muassasalari uchun asosiy boshqaruv platformasi sifatida joriy etilgan.

Mavjud adabiyotlarni tahlil qilib, quyidagi xulosa chiqarish mumkin: onlayn baholash tizimlari samarali bo‘lishi uchun ular mahalliy ta’lim tizimining spetsifik xususiyatlarini hisobga olishi, anti-cheating mexanizmlari bilan jihozlanishi va foydalanuvchi uchun qulay bo‘lishi zarur. HEMISMAS aynan shu bo‘shliqni to‘ldirish maqsadida yaratilgan.

TADQIQOT METODOLOGIYASI

Texnologik stek

Platforma quyidagi asosiy texnologiyalar kombinatsiyasiga qurilgan (1-jadval):

Komponent	Texnologiya / Vosita
Frontend	HTML5, CSS3, Vanilla JavaScript (ES6+)
Backend-as-a-Service	Supabase (PostgreSQL, Auth, Storage, RLS)
Hosting / CDN	Netlify (jamstack, avtomatik deployment)
Yuzni aniqlash	Google MediaPipe FaceMesh
Sun’iy intellekt	Groq API (Llama-3.3-70b-versatile)
QR kodlar	qrcode.js (npm)
PDF generatsiya	jsPDF

Xarita / Geolokatsiya	**Leaflet.js + OpenStreetMap + HTML5 Geolocation**
Domen / URL	**hemismas.netlify.app**

1-jadval. HEMISMAS platformasida qo‘llangan texnologik stek

Tizim arxitekturasi. HEMISMAS uch qatlamli arxitekturaga ega: prezentatsiya qatlami (HTML/CSS/JS), biznes-mantiq qatlami (Supabase Edge Functions va RLS qoidalari) va ma’lumotlar qatlami (PostgreSQL jadvallar). Foydalanuvchilar uch rolda tizimga kiradi: administrator, o‘qituvchi va talaba. Har bir rol uchun alohida dashboard va huquqlar to‘plami belgilangan.

Tizimning asosiy jadvallar tarkibi: users (foydalanuvchilar), tests (testlar), questions (savollar), attempts (urinishlar), enrolled_tests (ro‘yxatga olish). Row Level Security (RLS) yordamida har bir foydalanuvchi faqat o‘ziga tegishli ma’lumotlarga murojaat qila oladi.

Anti-cheating mexanizmlari. Platforma beshta asosiy anti-cheating usulini qo‘llaydi:

1. To‘liq ekran rejimi (Fullscreen API) — test boshlanishi bilan brauzer to‘liq ekranga o‘tadi; chiqish harakati testni avtomatik tugatadi.

2. Tab/oyna almashish nazorati (visibilitychange va blur hodisalar) — brauzer tabini almashtirish yoki oynani yopish darhol testni yakunlaydi.

3. Yuzni aniqlash (MediaPipe FaceMesh, 468 landmark) — test davomida talabaning yuzi kamera oldida bo‘lishi shart; burilish, berkitish yoki bir nechta yuz aniqlansa ogohlantirish va tugatish amalga oshiriladi. Birinchi 5 soniyada foydalanuvchi "yuz imzosi" (geometrik vektor) ro‘yxatga olinadi va har 30 soniyada solishtirilib impersonatsiya aniqlanadi.

4. Ovoz nazorati (Web Audio API, FFT analiz) — test davomida mikrofon orqali ovoz darajasi belgilangan chegaradan oshsa ogohlantirish yuborilib, ikkinchi marta takrorlansa test tugatiladi.

5. Geolokatsiya tekshiruvi (HTML5 Geolocation + Haversine formulasi) — o‘qituvchi xaritada markazni va radiusni belgilaydi; talaba faqat belgilangan hududda bo‘lgan taqdirda test topshira oladi.

TADQIQOT USULLARI

Tadqiqot davomida quyidagi metodlar qo‘llandi: tizim arxitekturasini tahlil qilish, funksionallik sinovlari (unit va integration testing), foydalanuvchi tajribasini baholash (UX testing) va ma’lumotlar xavfsizligi auditini o‘tkazish. Platforma https://hemismas.netlify.app manzilida joylashtirilgan va real foydalanuvchilar — talabalar va o‘qituvchilar — bilan sinab ko‘rilgan.

TAHLIL VA NATIJALAR

Platforma funksionalligi. HEMISMAS platformasini ishlab chiqish natijasida quyidagi asosiy modullar yaratildi va muvaffaqiyatli ishga tushirildi:

– Administrator panel — o‘qituvchi va talabalarni boshqarish, bloklash, statistika ko‘rish, PDF va QR natija yuklab olish.

– O‘qituvchi kabinetida test yaratish, ulashish (QR-kod, qisqa kod, Telegram va WhatsApp orqali), natijalarni ko‘rish va PDF eksport qilish.

– Talaba kabinetida mavjud testlarga kirish, tarix va yutuqlarni ko‘rish, mashq rejimida o‘rganish, QR-skanerlash orqali testga kirish.

– Natijalar sertifikati — har bir topshirilgan test uchun QR-kodli PDF sertifikat generatsiya qilinadi; sertifikat verify.html sahifasida tekshirilishi mumkin.

– Sun’iy intellekt tahlili — har bir test natijasidan keyin Groq Llama-3 modeli o‘zbek, rus va ingliz tillarida shaxsiy tavsiyalar beradi.

Texnik ko‘rsatkichlar. Jadval 2 da platformaning asosiy texnik xarakteristikalari keltirilgan:

Ko‘rsatkich	Qiymat / Tavsif
Sahifalar soni	10 ta HTML sahifa (index, login, teacher, student, admin, test, verify, privacy, terms, sitemap)
Ma’lumotlar bazasi	PostgreSQL (Supabase), 5 ta asosiy jadval + RLS
Autentifikatsiya	Supabase Auth (email/parol + Google OAuth)
Ko‘p tillilik	O‘zbek, Rus, Ingliz tillari (3 til)
PWA qo‘llab-quvvatlash	Service Worker, manifest.json, offline rejim
QR-kod	H darajali xato tuzatish, logo qo‘yish
Anti-cheat modullari	5 ta: fullscreen, tab, yuz, ovoz, geo
AI tahlil	Groq Llama-3.3-70b-versatile API
Joylashtirilgan manzil	https://hemismas.netlify.app

2-jadval. HEMISMAS platformasining texnik ko‘rsatkichlari

Xavfsizlik va ma’lumotlar himoyasi. Platformada ma’lumotlar xavfsizligini ta’minlash uchun bir necha qatlam qo‘llangan. PostgreSQL Row Level Security (RLS) mexanizmi orqali har bir foydalanuvchi faqat o‘ziga tegishli ma’lumotlarga murojaat qilishi ta’minlangan. HTTPS orqali shifrlangan aloqa, Supabase anon key asosida autentifikatsiya va parollarni ochiq saqlash taqiqi joriy etilgan. Talabalar shaxsiy ma’lumotlari minimal zaruriyat prinsipi asosida to‘planadi.

Platformalararo taqqoslash. Mavjud o‘xshash yechimlar bilan solishtirganda HEMISMAS quyidagi jihatlar bilan ajralib turadi (3-jadval):

Xususiyat	HEMISMAS	Google Forms	Moodle
Mahalliy adaptatsiya	Ha (O‘zbek tizimi)	Yo‘q	Qisman
Anti-cheating	5 ta modul	Yo‘q	Qisman
AI tahlil	Groq Llama-3	Yo‘q	Yo‘q
QR sertifikat	Ha	Yo‘q	Yo‘q
Bepul joylashtirilgan	Ha	Ha	Server talab qiladi
Ko‘p tillilik	3 til (UZ/RU/EN)	Cheklangan	Ko‘p tillik

3-jadval. HEMISMAS va boshqa platformalar taqqoslamasi

XULOSA VA TAKLIFLAR

Ushbu tadqiqot natijasida HEMISMAS — oliy ta'lim muassasalari uchun onlayn testlash va baholash jarayonlarini avtomatlashtiruvchi to'liq funksional veb-platforma yaratildi va muvaffaqiyatli ishga tushirildi. Platforma zamonaviy veb-texnologiyalar (HTML5/CSS3/JS, Supabase, Netlify), sun'iy intellekt (Groq Llama-3), MediaPipe yuzni aniqlash va ko'p qatlamli xavfsizlik mexanizmlarini birlashtirgan holda o'zbekistonlik ta'lim muassasalarining ehtiyojlarini qondiruvchi yechim sifatida taqdim etildi.

Tadqiqot natijalari shuni tasdiqlaydi: ochiq texnologiyalar asosida, maxsus moliyalashtirishsiz ham oliy ta'lim uchun raqobatbardosh raqamli baholash platformasini yaratish mumkin. Platforma o'qituvchi-talaba munosabatlarini raqamlashtirish, baholashni obyektivlashtirish va ta'lim jarayonining samaradorligini oshirishda muhim amaliy ahamiyatga ega.

Kelajakdagi tadqiqotlar uchun quyidagi takliflar ilgari suriladi: HEMIS davlat tizimi bilan to'liq API integratsiyasi, mobil ilovalar (Flutter/React Native) yaratish, bank darajasidagi autentifikatsiya tizimi joriy etish, real vaqt kooperativ test o'tkazish imkoniyatini qo'shish va adaptiv test algoritmlarini takomillashtirish.

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MASHINA-TRAKTOR AGREGATLARINING ISH SAMARADORLIGINI BAHOLASH VA OPTIMALLASHTIRISHNING INTEGRAL DINAMIK MODELI

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Annotatsiya. *Mashina-traktor agregatlari (MTA)ning samaradorligi texnik holat, ekspluatatsion rejimlar, tashqi muhit omillari va operator faoliyati ta’sirida shakllanadi. Mavjud tadqiqotlarda mazkur omillar aksariyat hollarda alohida ko‘rib chiqilgan bo‘lib, bu real ish sharoitida agregatlar faoliyatini kompleks baholash imkoniyatini cheklaydi. Ushbu maqolada inson–mashina–muhit tizimi konsepsiyasi asosida mashina-traktor agregatlarining mahsuldorligi va yoqilg‘i sarfini baholash uchun yagona dinamik matematik model ishlab chiqilgan. Model ishchi, transport va bekor turish rejimlaridagi yoqilg‘i sarfini hisobga oladi hamda texnik holat, tashqi muhit va operator charchashini ifodalovchi koeffitsientlarni o‘z ichiga oladi. Integral samaradorlik ko‘rsatkichi yordamida mahsuldorlik va resurs sarfi birgalikda baholanadi. Hisoblash natijalari texnik holat yomonlashganda yoqilg‘i sarfi 10–25 % ga ortishini hamda optimal yuklanish koeffitsienti $K_{load} \approx 0,8$ ekanligini ko‘rsatdi. Taklif etilgan model energiya samaradorligini oshirish, ekspluatatsion xarajatlarni kamaytirish va texnik xizmat ko‘rsatish intervallarini asoslash uchun amaliy ahamiyatga ega.*

Kalit so‘zlar: *mashina-traktor agregati, dinamik modellashtirish, yoqilg‘i sarfi, integral samaradorlik, inson–mashina–muhit tizimi, operator charchashi, energiya samaradorligi.*

Аннотация. *Эффективность машинно-тракторных агрегатов (МТА) формируется под воздействием технического состояния, эксплуатационных режимов, факторов окружающей среды и деятельности оператора. В большинстве существующих исследований данные факторы рассматриваются раздельно, что ограничивает возможности комплексной оценки работы агрегатов в реальных условиях эксплуатации. В данной статье на основе концепции системы «человек–машина–среда» разработана единая динамическая математическая модель оценки производительности и расхода топлива машинно-тракторных агрегатов. Предлагаемая модель учитывает расход топлива в рабочих, транспортных и холостых режимах, а также включает коэффициенты, характеризующие техническое состояние, влияние внешней среды и утомляемость оператора. Для комплексной оценки производительности и потребления ресурсов введён интегральный показатель эффективности. Результаты расчётов показали, что при ухудшении технического состояния расход топлива возрастает на 10–25 %, а оптимальное значение коэффициента загрузки составляет $K_{load} \approx 0,8$.*

Разработанная модель имеет практическое значение для повышения энергетической эффективности, снижения эксплуатационных затрат и обоснования интервалов технического обслуживания.

Ключевые слова. *Машинно-тракторный агрегат; динамическое моделирование; расход топлива; интегральная эффективность; система «человек–машина–среда»; утомляемость оператора; энергетическая эффективность; оптимизация работы.*

Abstract. *The performance of machine–tractor aggregates (MTAs) is determined by the combined influence of technical condition, operating regimes, environmental factors, and operator activity. In most existing studies, these factors are considered separately, which limits the possibility of a comprehensive assessment of aggregate performance under real operating conditions. This paper presents a unified dynamic mathematical model for evaluating the productivity and fuel consumption of machine–tractor aggregates based on the human–machine–environment system concept. The proposed model accounts for fuel consumption in working, transport, and idle operating modes and incorporates coefficients representing technical condition, environmental influences, and operator fatigue. An integral efficiency index is introduced to evaluate productivity and resource consumption simultaneously. The results show that fuel consumption increases by approximately 10–25% as the technical condition deteriorates, while the optimal load coefficient is found to be* $K_{load} \approx 0.8$*. The proposed model has practical significance for improving energy efficiency, reducing operating costs, and substantiating maintenance service intervals.*

Keywords. *Machine–tractor aggregate; dynamic modeling; fuel consumption; integral efficiency; human–machine–environment system; operator fatigue; energy efficiency; performance optimization.*

KIRISH

Zamonaviy qishloq xo‘jaligida energiya resurslaridan oqilona foydalanish va ishlab chiqarish xarajatlarini kamaytirish muhim vazifalardan biri hisoblanadi. Bu vazifani hal etishda mashina-traktor agregatlarining (MTA) ish samaradorligi hal qiluvchi ahamiyatga ega. Traktorlar va qishloq xo‘jaligi mashinalarining mahsuldorligi hamda yoqilg‘i sarfi qishloq xo‘jaligi mahsulotlari tannarxiga bevosita ta’sir ko‘rsatadi [1,2].

An’anaviy modellarda MTA ishlashi asosan dvigatel quvvati, harakat tezligi va tortish kuchiga bog‘liq holda baholanadi [1]. Biroq amaliyotda agregatlar ishiga tuproqning mexanik tarkibi, namlik darajasi, relef, iqlim sharoiti, texnik holat va operator mahorati kabi omillar ham sezilarli ta’sir ko‘rsatadi [3,4]. So‘nggi yillarda traktorlar ishlashini baholash uchun dinamik modellashtirish va mashinali o‘qitish usullaridan foydalanishga qiziqish ortmoqda [5,6].

O‘zbekiston sharoitida mashina-traktor agregatlaridan foydalanish samaradorligini oshirish bo‘yicha nazariy va amaliy tadqiqotlar olib borilgan [9]. Qator oralariga ishlov beruvchi agregatlar harakatining ehtimoliy xususiyatlari va ish sifatiga ta’sir etuvchi omillar ham o‘rganilgan [10]. Qishloq xo‘jaligi mashinalarining energiya tejamkor ish organlarini takomillashtirish bo‘yicha tadqiqotlar esa [11] manbalarda keltirilgan

Biroq aksariyat tadqiqotlarda inson omili, texnik holat va ekspluatatsion rejimlar o‘zaro bog‘liq holda ko‘rib chiqilmagan.

Shu munosabat bilan mazkur tadqiqotning maqsadi inson–mashina–muhit tizimi konsepsiyasi asosida mashina-traktor agregatlarining mahsuldorligi va yoqilg‘i sarfini baholash hamda optimallashtirish uchun yagona dinamik model ishlab chiqishdan iborat.

TADQIQOT METODOLOGIYASI VA NAZARIY ASOSLAR

Mashina-traktor agregatining umumiy samaradorligi mahsuldorlik, xarajatlar, texnik holat, inson omili va tashqi muhit ta’siri orqali shakllanadi. Shuning uchun integral samaradorlik ko‘rsatkichi quyidagicha ifodalandi:

$$\eta_{\text{int}} = f(Q, C, R, O, t, E, W), \quad (1)$$

bu yerda Q – mahsuldorlik; C – ekspluatatsion xarajatlar; R – texnik holat; O – operator omili; E – tashqi muhit ta’siri; W – agrotexnik talablarning bajarilish darajasini ifodalovchi ko‘rsatkich. t – vaqt.

Tenglama (1) agregat ishlashining kompleks xususiyatini aks ettiradi va barcha asosiy omillarni yagona tizimga birlashtiradi.

Mahsuldorlik modeli. Mashina-traktor agregatining soatlik mahsuldorligi quyidagi formula orqali aniqlanadi:

$$Q = 0.1 \cdot B \cdot v \cdot K_{\text{time}} \cdot K_{tech}, \quad (2)$$

bu yerda B – ish kengligi, m; v – harakat tezligi, km/soat; K_{time}– vaqtdan foydalanish koeffitsienti; K_{tech} – texnologik samaradorlik koeffitsienti.

(2) tenglamadan mahsuldorlik agregatning konstruktiv parametrlari bilan bir qatorda ish vaqtidan foydalanish darajasiga ham bog‘liqligi kelib chiqadi.

Ekspluatatsion xarajatlar. Umumiy ekspluatatsion xarajatlar quyidagicha ifodalanadi:

$$C_{exp} = C_f + C_{ts} + C_{sp} + C_{op}, \quad (3)$$

bu yerda C_f– yoqilg‘i va moylash materiallari xarajatlari; C_{ts} – texnik xizmat va ta’mirlash xarajatlari; C_{sp} – ehtiyot qismlar xarajatlari; C_{op} – operator mehnati bilan bog‘liq xarajatlar.

Amaliyotda yoqilg‘i xarajatlari umumiy xarajatlarning 40–60 % qismiga to‘g‘ri keladi [2].

Yoqilg‘i sarfining dinamik modeli. Dvigatelning nominal yoqilg‘i sarfi quyidagi tenglama orqali aniqlanadi:

$$G_{f0} = \frac{N_e \cdot q_e}{1000}, \quad (4)$$

bu yerda N_e – dvigatelning samarali quvvati, kVt; q_e – solishtirma yoqilg‘i sarfi, g·kVt^{-1}·soat^{-1}.

Tenglama (4) energiya balansiga asoslangan bo‘lib, yoqilg‘i sarfi va dvigatel quvvati o‘rtasidagi to‘g‘ri proporsional bog‘lanishni ifodalaydi.

Texnik holat ta’siri. Agregatning texnik holati yomonlashishi bilan mexanik yo‘qotishlar ortadi va yoqilg‘i sarfi ko‘payib boradi. Bu holat texnik koeffitsient orqali hisobga olinadi:

$$G_f = K_i \cdot G_{f0}, \quad (5)$$

bu yerda K_i– texnik holat koeffitsienti.

U quyidagi ko‘rinishda aniqlanadi:

$$K_i = \frac{\eta_{new}}{\eta_{wear}}, \quad (6)$$

bu yerda η_{new} va η_{wear} mos ravishda yangi va yeyilgan agregat samaradorligini ifodalaydi.

Amaliyot uchun soddalashtirilgan ko‘rinish:

$$K_i = 1 + \gamma_{th}\,\delta, \quad (7)$$

bu yerda δ – yeyilish darajasi; γ_{th} – konstruktiv sezgirlik koeffitsienti.

Tajriba ma’lumotlariga ko‘ra texnik holat yomonlashganda yoqilg‘i sarfi 10–25 % ga ortishi mumkin [7].

Inson–mashina–muhit tizimi modeli. Real ekspluatatsiya sharoitida yoqilg‘i sarfiga tashqi muhit, texnik holat va inson omili bir vaqtning o‘zida ta’sir qiladi. Shu sababli umumlashtirilgan dinamik model taklif etildi:

$$G_f(t) = K_{load} \cdot K_i \cdot K_h(t) \cdot \frac{N_e \cdot q_e}{1000}\ (1+\alpha), \quad (8)$$

bu yerda K_{load} – yuklanish koeffitsienti; K_i– texnik holat koeffitsienti; $K_h(t)$– inson omili koeffitsienti; α – moy sarfi koeffitsienti.

Yuklanish koeffitsienti quyidagicha aniqlanadi:

$$K_{load} = \frac{N_{req}}{N_{nom}}, \quad (9)$$

bu yerda N_{req} – talab etiladigan quvvat; N_{nom} – nominal quvvat.

Muhit omillarining umumiy ta’siri K_{env} koeffitsienti orqali hisobga olindi:

$$K_{\text{env}} = K_{soil} \cdot K_{moist} \cdot K_{relief} \cdot K_{climate}, \quad (10)$$

bu yerda tuproq, namlik, relef va iqlim ta’siri hisobga olinadi.

Operator charchashi modeli. Operatorning uzluksiz ishlashi mahsuldorlikning pasayishiga olib keladi. Bu holat eksponensial funksiya orqali ifodalandi:

$$K_h(t) = exp(-\beta t), \quad (11)$$

bu yerda β – charchash intensivligi koeffitsienti; t – ish vaqti.

Tenglama (11) vaqt o‘tishi bilan operator samaradorligining pasayishini tavsiflaydi [8].

Ko‘p rejimli yoqilg‘i sarfi modeli. MTA ishchi, transport va bekor turish rejimlarida faoliyat ko‘rsatadi. Ularning vaqt ulushlari:

$$\sum_j \tau_j = 1, \qquad 0 \le \tau_j \le 1. \quad (12)$$

bu yerda τ_j – joriy rejimning vaqt ulushi.

Umumiy yoqilg‘i sarfi:

$$G_f^{tot}(t) = \sum_j \tau_j\ G_{f,j}(t) + G_{aux}, \quad (13)$$

bu yerda $G_{f,j}$ – j-rejimdagi yoqilg‘i sarfi; G_{aux} – yordamchi tizimlar sarfi.

Shunday qilib, model real ish jarayonidagi barcha rejimlarni hisobga oladi.

Integral samaradorlik ko‘rsatkichi. MTA samaradorligini kompleks baholash uchun quyidagi ko‘rsatkich taklif etildi:

$$\eta_{int} = \frac{Q_{useful}}{Q_{total}},$$

yoki

$$\eta_{\text{int}}(t) = \frac{\tau_{work}(0.1\,B\,v\,K_{\text{time}}\cdot K_{tech})\cdot(k_{skill}\cdot k_{erg}\,e^{-\beta t})\cdot W(t)}{\sum_j \tau_j\cdot\left[\frac{N_{req,j}\cdot q_{e,j}}{1000\cdot\eta_{tr}\cdot\eta_{eng}}(1+\alpha)\cdot(\prod K_{env,j})\cdot K_i\cdot K_h(t)\cdot(1+\kappa(t))\right]+\ G_{aux}}. \quad (14)$$

bu yerda τ_{work} – umumiy ish vaqtida ishchi rejimning ulushi; k_{skill} – operatorning malaka darajasini ifodalovchi koeffitsient; k_{erg} – mehnat sharoiti va ergonomik omillarni hisobga oluvchi koeffitsient; W(t) – agrotexnik talablarni bajarish darajasini tavsiflovchi funksiya; G_{aux} – yordamchi tizimlar (gidravlik tizim, konditsioner va boshqalar) uchun sarflanadigan yoqilg‘i miqdori; $\kappa(t)$ – ekspluatatsiya jarayonida yuzaga keluvchi qisqa muddatli dinamik o‘zgarishlarni hisobga oluvchi tuzatish koeffitsienti. Qolgan parametrlar mazkur ishning oldingi bo‘limlarida keltirilgan.

Ushbu ko‘rsatkich mahsuldorlik, operator samaradorligi va agrotexnik talablarni bajarish darajasini umumiy yoqilg‘i sarfi bilan bog‘lab, mashina-traktor agregatining real ish sharoitidagi kompleks samaradorligini baholash imkonini beradi. Integral samaradorlik ko‘rsatkichining ortishi agregatdan foydalanish samaradorligi oshganligini, kamayishi esa resurs sarfining mahsuldorlikka nisbatan o‘sganligini ko‘rsatadi.

NATIJALAR VA MUHOKAMA

Model New Holland TD5 110 DF va MTZ–100 traktorlari uchun qo‘llanildi.

1-jadval

Yuklanish koeffitsientining samaradorlikka ta’siri

K_{load}	Yoqilg‘i sarfi, l/soat	η_{int}
0.4	5.6	0.63
0.6	6.9	0.74
0.8	7.8	0.82
1.0	9.4	0.71

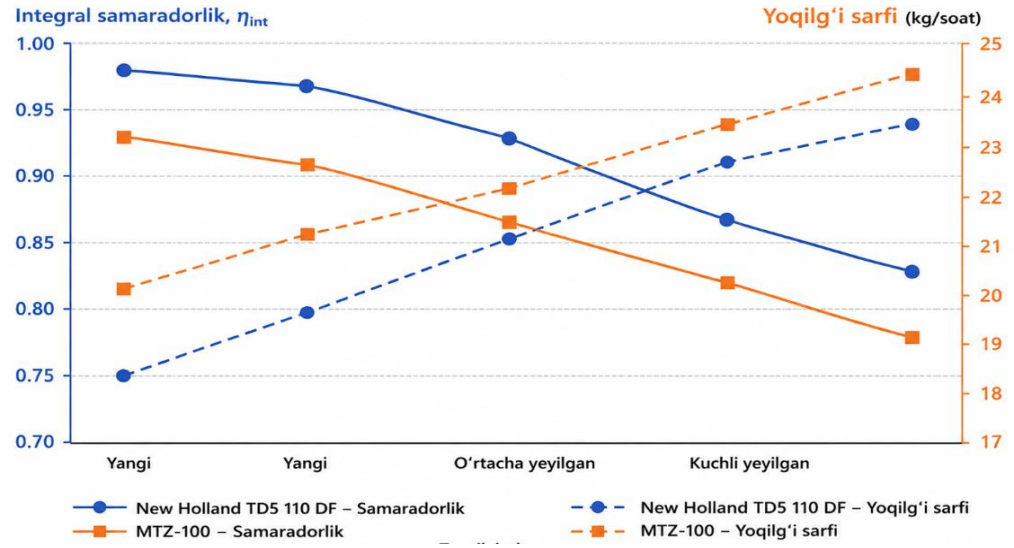
1-jadval ma’lumotlaridan ko‘rinishicha, integral samaradorlik koeffitsienti K_{load} =0.8 da maksimal qiymatga ega. Bu natija dvigatel quvvatidan samarali foydalanish va yoqilg‘i sarfi o‘rtasidagi optimal muvozanatni ifodalaydi.

2-jadval

Texnik holatga qarab yoqilg‘i sarfi

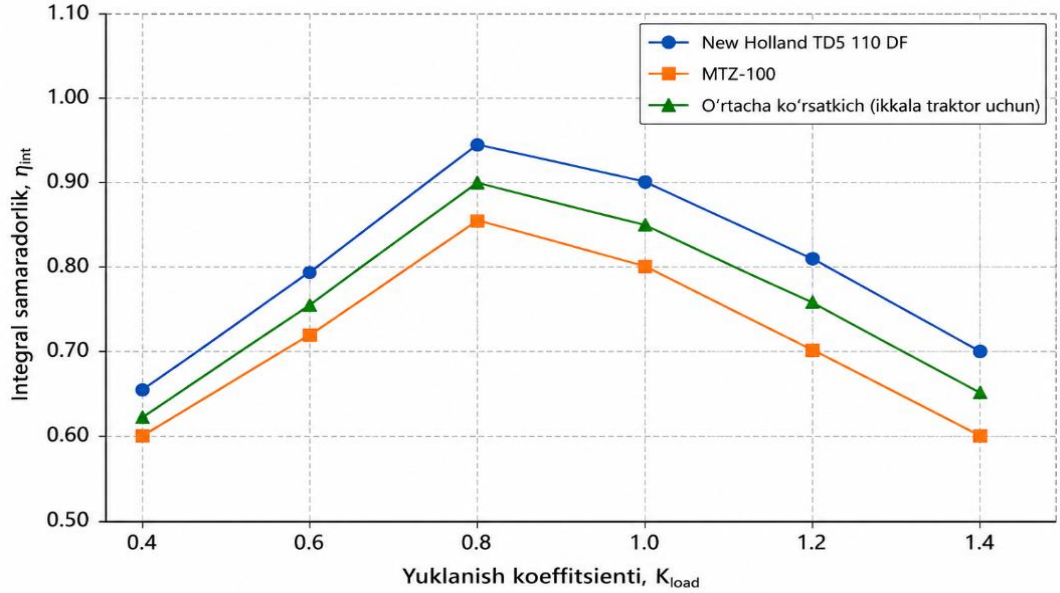
Holat	TD5 110 DF	MTZ-100
Yangi	17.8	19.5
O‘rtacha yeyilgan	19.6	21.8
Kuchli yeyilgan	22.1	24.7

New Holland TD5 110 DF traktorida yoqilg‘i sarfi yangi holatdan kuchli yeyilgan holatga o‘tganda 24,2 % ga, MTZ-100 traktorida esa 26,7 % ga ortgan. Bu MTZ-100 modelining texnik yeyilishga nisbatan sezgirligi yuqoriroq ekanligini ko‘rsatadi. Texnik holat yomonlashishi natijasida har ikki traktorda yoqilg‘i sarfi sezilarli darajada oshgan. Bu holat mexanik yo‘qotishlarning ortishi bilan izohlanadi.



1-rasm. Texnik holat o'zgarishining New Holland TD5 110 DF va MTZ-100 traktorlarining yoqilg'i sarfi hamda integral samaradorlik ko'rsatkichlariga ta'siri.

1-rasmdagi grafiklar texnik holat yomonlashishi bilan har ikki traktorda yoqilg'i sarfi ortib, integral samaradorlik pasayishi kuzatildi. New Holland TD5 110 DF traktori barcha holatlarda MTZ-100 ga nisbatan yuqori samaradorlik va past yoqilg'i sarfini namoyon qildi. Natijalar texnik holatni o'z vaqtida saqlash va texnik xizmat ko'rsatish agregatlarning energiya samaradorligini oshirishda muhim ahamiyatga ega ekanligini ko'rsatadi.



2-rasm. Integral samaradorlikning yuklanish koeffitsientiga bog'liqligi.

Integral samaradorlik yuklanish koeffitsienti ortishi bilan Kload=0,8 gacha o'sadi va shu nuqtada maksimal qiymatga erishadi. Keyingi yuklanish ortishi samaradorlikning pasayishiga olib keladi. Bu holat har ikki traktor uchun optimal ish rejimi Kload≈0,8 atrofida shakllanishini ko'rsatadi. New Holland TD5 110 DF traktori barcha yuklanish diapazonida MTZ-100 ga nisbatan yuqori samaradorlikni ta'minlagan.

Natijalar [3], [4] va [7] manbalarda keltirilgan eksperimental ma'lumotlar bilan mos keladi.

8. Xulosalar. Tadqiqot natijalari taklif etilgan modelning mashina-traktor agregatlari samaradorligini baholash va energiya sarfini kamaytirish masalalarini hal etishda samarali ekanligini tasdiqladi:

1. Mashina-traktor agregatlarining ish samaradorligini baholash uchun inson–mashina–muhit tizimiga asoslangan yagona dinamik model ishlab chiqildi;
2. Model texnik holat, tashqi muhit ta'siri va operator charchashini hisobga oladi;
3. Texnik holat yomonlashganda yoqilg'i sarfi 10–25 % ga ortishi aniqlandi;
4. Integral samaradorlikning maksimal qiymati $K_{load} \approx 0.8$ bo'lganda kuzatildi;
5. Taklif etilgan model energiya sarfini kamaytirish, texnik xizmat ko'rsatish intervallarini asoslash va ekspluatatsiya samaradorligini oshirish uchun qo'llanilishi mumkin.

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MEXANIZATSIYALASHGAN USULDA EKISH UCHUN U-SHAKLLI PARABOLIK SIRTLI ISHCHI ORGANNI EKSPERIMENTAL ASOSLASH

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Annotatsiya. *Mazkur tadqiqotda qalamchalarni mexanizatsiyalashgan usulda ekish uchun U-shaklli parabolik model asosida ifodalanib, tuproq–ishchi organ o‘zaro ta’sirini tavsiflovchi noliney dinamik tenglama ishlab chiqildi. Kanal devori qiyaligi va tuproqning ichki ishqalanish burchagi o‘rtasidagi bog‘lanish asosida tuproqning kanalga qayta to‘kilish sharti analitik ravishda aniqlandi. Qalamchaning zichlashgacha bo‘lgan masofada vertikal barqarorligini ta’minlovchi minimal tayanch tuproq hajmi sharti asoslandi. Dala sharoitida o‘tkazilgan tajribalar natijasida kanal geometriyasining barqaror shakllanishi, tuproqning nazoratli qayta to‘kilishi va qalamchalarning 3–5° dan oshmagan vertikal og‘ishi tasdiqlandi. Parabola koeffitsienti a, kanal yarim kengligi X_{max} va harakat tezligi v uchun maqbul qiymatlar sohasi aniqlanib, taklif etilgan konstruksiyaning amaliy samaradorligi isbotlandi.*

Keywords. *qalamcha ekish; U-shaklli parabolik ishchi organ; kanal geometriyasi; qayta to‘kilish sharti; vertikal barqarorlik; geometrik optimallashtirish; mexanizatsiyalashgan ekish.*

Аннотация. *В данном исследовании для механизированной посадки черенков было разработано нелинейное динамическое уравнение, описывающее взаимодействие почвы с рабочим органом и основанное на U-образной параболической модели. На основе зависимости между углом наклона стенки канала и углом внутреннего трения грунта аналитически определено условие обратного осыпания грунта в канал. Обосновано условие минимального объёма опорного грунта, обеспечивающего вертикальную устойчивость черенка на расстоянии до уплотнения. В результате полевых экспериментов подтвердилось устойчивое формирование геометрии канала, контролируемое обратное осыпание почвы и вертикальное отклонение черенков, не превышающее 3–5°. Определена область оптимальных значений для коэффициента параболы a, полуширины канала Xmax и скорости движения v, что доказывает практическую эффективность предложенной конструкции.*

Ключевые слова: *посадка черенков; U-образный параболический рабочий орган; геометрия канала; условие пересыпания; вертикальная устойчивость; геометрическая оптимизация; механизированная посадка.*

Abstract. *In this study, a nonlinear dynamic equation was developed for mechanized planting of cuttings, describing the interaction between the soil and the working element and based on a U-shaped parabolic model. Based on the relationship between the slope angle of the canal wall and the internal friction angle of the soil, the condition for soil backflow into the canal was analytically determined. The condition for the minimum volume of supporting soil, which ensures the vertical stability of the cuttings at the distance to compaction, has been substantiated. As a result of field experiments, it was confirmed that the formation of the canal geometry is stable, soil backsliding is controlled, and the vertical deviation of the cuttings does not exceed 3–5°. The optimal range of values for the parabola coefficient a, the channel half-width Xmax, and the travel speed v has been determined, proving the practical effectiveness of the proposed design.*

Keywords: *planting cuttings; U-shaped parabolic working element; channel geometry; overflow condition; vertical stability; geometric optimization; mechanized planting.*

KIRISH

Qalamchalar bilan ko‘paytirish bog‘dorchilik va o‘rmon xo‘jaligida nav xususiyatlarini saqlab qolish hamda o‘simlik materialining bir xilligini ta’minlash uchun keng qo‘llaniladigan samarali vegetativ usuldir [1, 2, 11]. Qalamchalarning yashovchanligi barqaror ekish chuqurligiga, vertikal bo‘yicha aniq joylashishiga va tuproq bilan ishonchli kesish kontaktiga bog‘liq [2, 6, 12]. O‘zan geometriyasining buzilishi yoki tuproqning notekis to‘ldirilishi kesishning og‘ishiga va o‘rnatish samaradorligining pasayishiga olib kelishi mumkin.

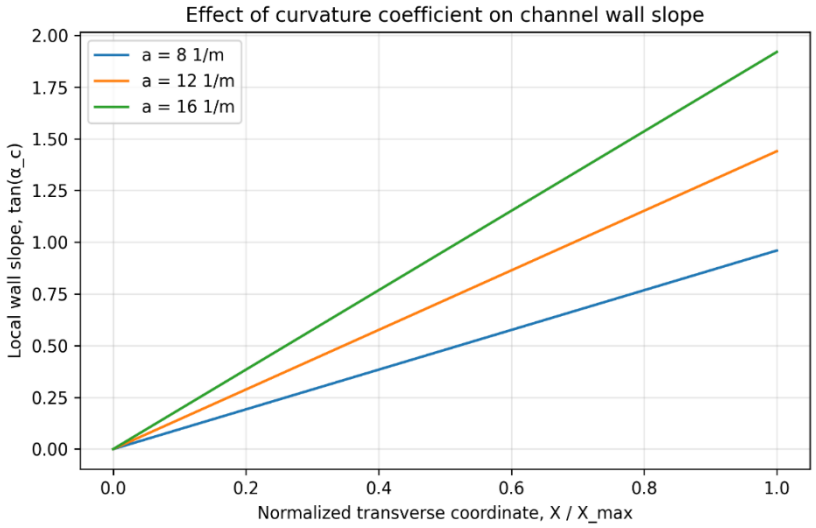
Mavjud ekish agregatlarining aksariyati asosan urug‘ yoki ko‘chat uchun mo‘ljallangan bo‘lib, vertikal kesish uchun zarur bo‘lgan tor va barqaror kanal hosil qilish texnologik talablarini to‘liq qanoatlantirmaydi [3, 9, 13]. Odatdagi yassi yoki ponasimon ishchi organlar ko‘pincha tuproqning haddan tashqari buzilishiga va kanal devorlarining notekis bo‘lishiga olib keladi [4, 7, 14].

Tuproq va asbobning o‘zaro ta’siri bo‘yicha o‘tkazilgan avvalgi tadqiqotlar shuni ko‘rsatdiki, asbob geometriyasi tuproqning qarshiligiga, deformatsiya mexanizmlariga va tuproqning yemirilish qonuniyatlariga sezilarli ta’sir ko‘rsatadi [3, 5, 8, 15]. Biroq, U-simon parabolik ishchi yuzaning o‘zan turg‘unligiga ta’siri va mexanizatsiyalashtirilgan kesma ekish paytida tuproqning boshqariladigan to‘ldirilishi yetarli darajada tahlil qilinmagan. Xususan, kanal devorining qiyaligini gruntning ichki ishqalanish burchagi bilan bog‘laydigan analitik shart aniq ifodalanmagan.

Tadqiqotning maqsadi mexanizatsiyalashgan ko‘chat ekish uchun U-simon parabolik yuzali ishchi organni nazariy va eksperimental asoslashdan iborat. O‘zan ko‘ndalang kesimining parabolik geometrik modeli ishlab chiqilgan, grunt-asbob o‘zaro ta’sirini tavsiflovchi nochiziqli dinamik tenglama keltirib chiqarilgan va gruntni qayta to‘ldirishning analitik sharti qo‘yilgan. Shuningdek, shlamlarni zichlashdan oldin vertikal turg‘unligini ta’minlovchi geometrik va mexanik talablar shakllantirilgan va tajribada tasdiqlangan.

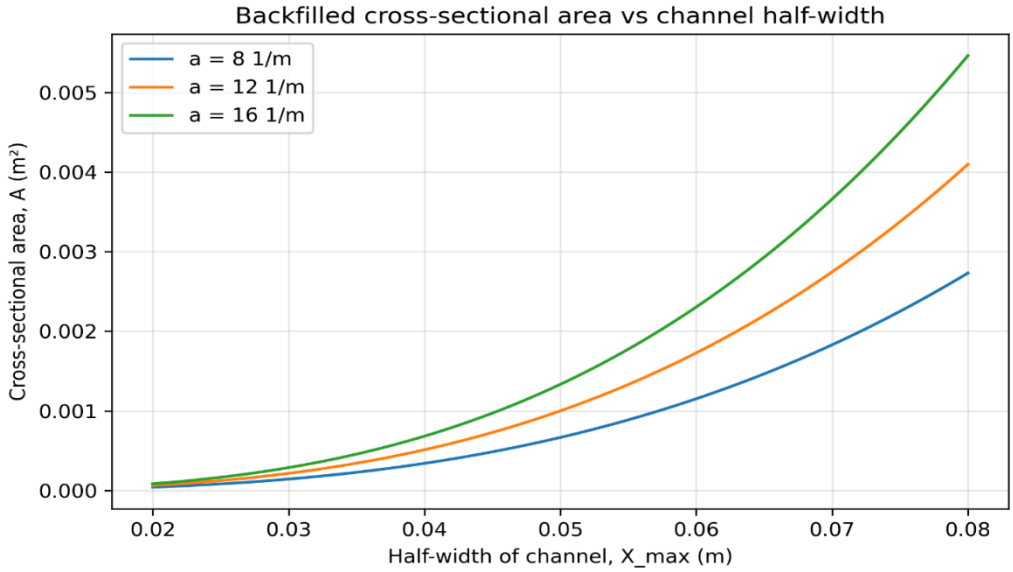
MATERIALLAR VA USULLAR

Tadqiqotning maqsadi - U-shaklli parabolik sirtli ishchi organ parametrlarini nazariy asoslash, tuproqning qayta to‘kilish mexanizmini tahlil qilish va qalamchaning vertikal barqarorligini ta’minlovchi geometrik hamda mexanik shartlarni aniqlashdan iborat.



1-rasm. Egrilik koeffitsiyenti a ning o‘zan devori nishabligiga ta’siri.

Parabolik egrilik koeffitsiyenti a ning turli qiymatlarida mahalliy devor nishabligi $\tan\alpha_c=2aX$ ning normallashtirilgan ko‘ndalang koordinata X/X_{max} bo‘yicha o‘zgarishi. a ning ortishi o‘zan devorining tikroq bo‘lishiga va tuproqni qayta to‘ldirish sharti $\tan\alpha_c>\tan\varphi$ ning ertaroq bajarilishiga olib keladi.



2-rasm. U-simon parabolik ishchi organning konstruktiv-geometrik sxemasi: 1 - lemex; 2 - U-simon parabolik ag‘dargich; 3 - tutqich; 4 - yo‘naltiruvchi naycha; 5 - kesuvchi kiritish elementi.

Ishchi yuzaning X-Z tekislikdagi ko‘ndalang profili $Z=aX^2$ parabolik tenglama bilan tavsiflanadi, bu yerda X - o‘zan o‘q chizig‘idan o‘lchangan gorizontal koordinata, X_{max} - o‘zan yarim kengligi, R (X) - mahalliy egrilik radiusi. Qabul qilingan geometriya tuproqning boshqariladigan siljishini va vertikal kesish uchun barqaror tor kanal hosil bo‘lishini ta’minlaydi.

Qalamcha tushirilgandan keyin kanalga tuproqning qayta to‘kilishi va vertikal barqarorlik sharti. Kombinatsiyalangan qalamcha ekish apparatida kanal U-shaklli parabolik kesimga ega deb qabul qilinadi. Kanal profili kanal kengligi bo‘ylab (1) tenglama bilan ifodalanadi.

Kanal devorining mahalliy qiyaligi hosila orqali aniqlanadi:

$$\frac{dZ}{dX} = 2aX\ , \tag{1}$$

Kanal devori burchagi:

$$tan\,\alpha_c = 2aX. \tag{2}$$

Maksimal qiyalik kanal yarim kengligi $X=X_{max}$ da:

$$tan\,\alpha_{c,max} = 2aX_{max}. \tag{3}$$

Kanal devoridagi tuproq elementiga og‘irlik kuchi $G=mg$, normal reaksiya N, ishqalanish kuchi $F_f=Ntan\varphi$ ta’sir qiladi.

Siljish sharti:

$$mgsin\alpha_c > mgcos\,\alpha_c\,tan\varphi. \tag{4}$$

Qisqartirib:

$$tan\alpha_c > tan\varphi \tag{5}$$

yoki

$$\alpha_c > \varphi. \tag{6}$$

bu yerda φ - tuproqning ichki ishqalanish burchagi.

(5) ni (4) ga qo‘ysak:

$$2aX_{max} > tan\,\varphi \tag{7}$$

Demak, kanal devori ichki ishqalanish burchagidan tik bo‘lsa, tuproq kanal ichiga qayta tushadi.

Kanal kesimi parabolik bo‘lgani uchun uning maydoni:

$$A = \int_{-Xmax}^{Xmax} aX^2 dX, \tag{8}$$

$$A = \frac{2aX_{max}^3}{3}. \tag{9}$$

Kanal uzunligi bo‘yicha:

$$V_{ch} = A \cdot L\ . \tag{10}$$

Qayta to‘kilgan qism:

$$V_r = \eta V_{ch}, \tag{11}$$

Qalamcha zichlash g‘ildiragigacha bo‘lgan masofada vertikal holatda turishi uchun minimal tayanch hajm talab etiladi:

$$V_r \geq V_{min} \tag{12}$$

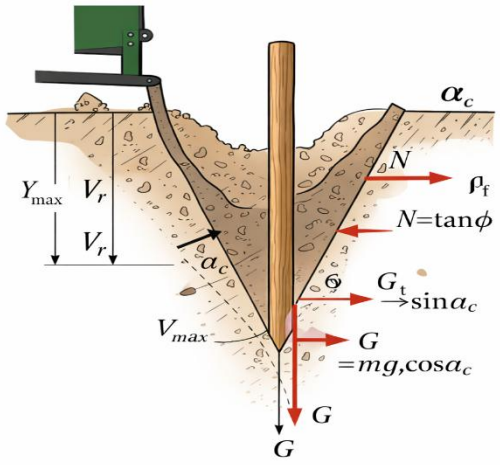
yoki

$$\eta V_{ch} \geq V_{min}. \quad (13)$$

Soddalashtirilgan holda:

$$V_{min} \approx b_s \; h_s \, l_s. \quad (14)$$

bu yerda b_s - tayanch qalinligi, h_s - tayanch balandligi, $l_s \leq l_g$ - barqarorlik zonasi



3-rasm. U-shaklli parabola sirtli kanal kesimida tuproqning qayta to‘kilishi va qalamchaning vertikal barqarorligini ta’minlash sxemasi: α_c - kanal devorining qiyalik burchagi; φ - tuproqning ichki ishqalanish burchagi; $G=mg$ - tuproq bo‘lagining og‘irlik kuchi; $G_t=mg\sin\alpha_c$ - qiyalik bo‘yicha harakatlantiruvchi proeksiya; $N=mg\cos\alpha_c$ - normal reaksiya; $F_f=N\tan\varphi$ - ishqalanish kuchi; V_r - kanalga qayta to‘kilgan tuproq hajmi; X_{max} - kanal yarim kengligi;

1-jadvalda kanalga qayta to‘kilish shartini belgilaydigan asosiy parametrlar keltirilgan.

1-jadval.

Tuproqning qayta to‘kilishini belgilovchi asosiy parametrlar va shartlar

Parametr	Fizik ma’nosi	Asosiy shart
a, X_{max}, φ	kanal devori qiyaligi	$2aX_{max}>\tan\varphi$ (ya’ni $\alpha_c>\varphi$)
η, V_{ch}, V_{min}	qayta to‘kilish hajmi	$\eta V_{ch} \geq V_{min}$
l_g	zichlashgacha masofa	l_g=0.45–0.5 m

Shunday qilib, U-shaklli parabola sirtli okuchnikda kanal devorining qiyaligi α_c tuproqning ichki ishqalanish burchagi φ dan katta bo‘lganda ($\alpha_c>\varphi$) kanal devorlari barqarorligini yo‘qotib, tuproq massasining ma’lum qismi kanal ichiga qayta to‘kiladi. Qalamchaning zichlash g‘ildiragigacha bo‘lgan masofada ($l_g\approx0,5$ m) vertikal holatda saqlanishi uchun qayta to‘kilgan tuproq hajmi $V_r = \eta V_{ch}$ minimal talabdan kam bo‘lmasligi, ya’ni $\eta V_{ch} \geq V_{min}$ sharti bajarilishi zarur.

Eksperiment o‘tkazish sharoiti. Taklif etilgan U-shaklli parabolik sirtli ishchi organning ish samaradorligini baholash maqsadida dala sharoitida tajribalar o‘tkazildi.

Tajriba o‘tkazilgan maydon oldindan agrotexnik talablarga muvofiq tayyorlangan bo‘lib, tuproq mexanik tarkibi bo‘yicha o‘rtacha qumoq (srednesuglinistaya) turga mansub. Eksperiment davrida tuproq namligi – 14–17 %, tuproq zichligi – 1,32–1,38 g/sm³, dala yuzasi tekislangan holatda edi.

Kombinatsiyalangan qalamcha ekish apparati traktorga agregatlangan holda ishlatildi (4-rasm). Bir o‘tishda kanal ochish, qalamchani tushirish va tuproqni qayta qoplash jarayonlari amalga oshirildi.

4-rasm. Dala sharoitida qalamchalar ekilib, hosil qilingan kanal va qatorlar barqarorligining umumiy ko‘rinishi.

Eksperimentlarda qo‘llanilgan qalamcha ekish agregatining sinov-tajriba namunasi 5, 6-rasmlarda keltirilgan.

5-rasm. Kombinatsiyalangan qalamcha ekish apparatining traktorga agregatlangan holati.

6-rasm. Ishchi organning yon ko‘rinishi va qoplash-zichlash tizimi.

2-jadval.

Eksperiment o‘tkazishda qabul qilingan ish parametrlari

Ko‘rsatkich	Belgisi	Qiymat
Harakat tezligi	v	1,2–1,6 m/s
Ish chuqurligi	h	0,18–0,22 m
Kanal yarim kengligi	X_{max}	0,05–0,07 m
Parabola koeffitsienti	a	10–16 1/m
Zichlashgacha masofa	l_g	0,5 m

Ishchi organ samaradorligi quyidagi ko‘rsatkichlar asosida baholandi:

1. Kanal geometriyasining barqarorligi;
2. Qalamchaning vertikal og‘ish burchagi;
3. Kanalga tuproqning qayta to‘kilish sifati;
4. Tuproq buzilish intensivligi.

Kanal profili o‘lchash shablonlari yordamida tekshirildi. Qalamcha og‘ishi maxsus o‘lchash asbobi orqali aniqlandi.

Eksperiment natijalarining ishonchliligini baholash maqsadida har bir ish rejimi uchun n=3–5 marta takroriy tajriba o‘tkazildi. Har bir ko‘rsatkich bo‘yicha (kanal geometriyasi barqarorligi, qalamchaning og‘ish burchagi θ, qayta to‘kilish sifati va h.k.) o‘rtacha qiymat, standart og‘ish va 95% ishonchlilik intervali hisoblandi.

Shu yo‘l bilan eksperiment ma’lumotlarining takrorlanuvchanligi va parametrlar ta’sirining ahamiyatliligi ishonchli ravishda asoslandi.

NATIJALAR

Nazariy va eksperimental natijalari o‘zaro taqqoslandi va tahlil qilindi. Tajriba natijalari quyidagilarni ko‘rsatdi:

a) parabolik sirt kanalning barqaror shakllanishini ta’minladi;

b) Kanal devori qiyaligi ichki ishqalanish burchagidan katta bo‘lgan holatlarda tuproqning tabiiy qayta to‘kilishi kuzatildi;

s) Qalamchalarning vertikal og‘ishi 3–5° dan oshmadi va agrotexnik talablarga javob berdi;

d) Tuproqning ortiqcha sochilishi kuzatilmadi.

An’anaviy ponasimon ishchi organlar bilan taqqoslaganda, taklif etilgan konstruksiya kanal simmetriyasini yaxshiladi, qayta to‘kilish jarayonini birxillashtirdi, qalamcha atrofida tuproq bilan zich kontakt hosil qildi.

Muhokama. Eksperiment natijalari nazariy modelda olingan shartni tasdiqladi: $2aX_{max} > tan\varphi$.

Berilgan parametrlarda ushbu shart bajarildi va kanal devorlari orqali tuproqning nazoratli qayta to‘kilishi ta’minlandi.

Zichlash g‘ildiragigacha bo‘lgan masofa (l_g h 0,5 m) qalamchaning vertikal barqaror holatini saqlash uchun yetarli ekanligi aniqlandi.

Optimallashtirishning maqsadi - yuqoridagi cheklovlar bajarilgan holda kanal barqarorligini va qayta to‘kilishni ta’minlash, shu bilan birga ortiqcha tuproq buzilishi va siljishini minimallashtirishdan iborat.

Eksperimentda sinovdan o‘tkazilgan parametrlar diapazoni: v=1.2–1.6 m/s, X_{max}=0.05–0.07 m, a =10–16 m−1.

Shu diapazonlarda (1)–(2) shartlar va texnologik ko‘rsatkichlar yig‘indisiga tayanilgan holda maqbul soha quyidagicha tavsiya etiladi:

- **egrilik koeffitsienti:** a = 12–14 m^{-1} - kanal devorini yetarlicha tik qilib, qayta to‘kilishni barqaror ta’minlaydi; aaa ortishi esa ortiqcha siljishni kuchaytirishi mumkin.
- **kanal yarim kengligi:** X_{max}= 0.06 ± 0.01 m - kanal tor va simmetrik shakllanishi hamda qalamchaning vertikal joylashishi uchun qulay.
- **harakat tezligi:** v = 1.3–1.5 m/s - tezlik pasayganda texnologik unumdorlik kamayadi, ortib ketganda esa tuproq buzilishi va siljish intensivligi oshishi ehtimoli mavjud; shuning uchun o‘rta diapazon maqbul hisoblanadi.

Shunday qilib, a, X_{max} va v parametrlarini ko‘rsatilgan maqbul sohada tanlash kanal geometriyasining barqaror shakllanishini, tuproqning nazoratli qayta to‘kilishini hamda qalamchaning zichlashgacha bo‘lgan masofada vertikal barqarorligini ta’minlaydi.

Ushbu tadqiqotda U-shaklli parabolik kanal kesimida tuproqning nazoratli qayta to‘kilish sharti $2aX_{max}>tan\varphi$ analitik ravishda asoslandi va kanal devori qiyaligi hamda tuproqning ichki ishqalanish burchagi o‘rtasidagi funksional bog‘lanish ifodalandi. Parabolik ishchi sirt bo‘ylab tuproq zarrachalari harakatini tavsiflovchi noliney dinamik “tuproq–ishchi organ” modeli ishlab chiqilib, jarayonning asosiy parametrlari o‘lchamsiz ko‘rinishda ifodalandi. Qalamchaning zichlash g‘ildiragigacha bo‘lgan masofada vertikal holatda saqlanishini ta’minlovchi minimal tayanch tuproq hajmi sharti nazariy jihatdan aniqlandi va uning geometrik parametrlar bilan bog‘lanishi ko‘rsatildi. Shuningdek, parabola koeffitsienti aaa va kanal yarim kengligi X_{max} ni maqbul tanlash asosida kanal barqarorligi, tuproqning nazoratli qayta to‘kilishini hamda qalamchaning vertikal barqarorligini ta’minlovchi geometrik optimallashtirish yondashuvi taklif etildi.

Dala sharoitida o‘tkazilgan tajribalar U-shaklli parabola sirtli ishchi organ:

Eksperiment natijalari kanalning barqaror va simmetrik shakllanishini tasdiqladi; qalamchalarning vertikal og‘ishi 3–5° dan oshmadi va tuproqning nazoratli qayta to‘kilishi ta’minlandi.

Parametrlarni optimallashtirish natijasida egrilik koeffitsienti a=12–14 m^{-1}, kanal yarim kengligi X_{max}=0.06±0.01 m va harakat tezligi v=1.3–1.5 m/s diapazonida eng barqaror texnologik rejim aniqlandi.

Taklif etilgan konstruksiya an’anaviy ishchi organlarga nisbatan kanal barqarorligini oshirishi, tuproq buzilishini kamaytirishi va qalamcha ekish sifati yaxshilanishini ta’minlashi eksperimental ravishda tasdiqlandi.

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PARABOLIK U-SHAKLLI ISHCHI ORGANLI QALAMCHA EKISH APPARATINING NAZARIY VA EKSPERIMENTAL ASOSLARI

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Annotatsiya. *Maqolada qalamchalarni mexanizatsiyalashgan usulda ekish uchun mo‘ljallangan parabolik U-shaklli ishchi organga ega kombinatsiyalangan ekish apparatining konstruksiyasi va nazariy asoslari keltirilgan. Taklif etilgan ishchi organ tuproqda tor va barqaror kanal hosil qilish, qalamchani belgilangan chuqurlikda vertikal holatda joylashtirish hamda tuproqning kanalga qisman qayta tushishi hisobiga uning dastlabki barqarorligini ta’minlashga xizmat qiladi. Ishchi organ sirtining geometrik modeli parabolik tenglama asosida ishlab chiqildi, kanal parametrlari va mahalliy egrilik radiusini aniqlash ifodalari olindi. Tuproqning kanalga qayta tushish sharti tuproqning ichki ishqalanish burchagi va ishchi organ sirti qiyaligi o‘rtasidagi bog‘lanish orqali nazariy jihatdan asoslandi. Eksperimental tadqiqotlarda parabola koeffitsientining kanal geometriyasi va qalamchaning vertikal joylashish sifatiga ta’siri baholandi. Natijalar parabolik U-shaklli ishchi organ an’anaviy okuchniklarga nisbatan kanal barqarorligini oshirishi, qalamcha og‘ish burchagini kamaytirishi va ekish sifatini yaxshilashini ko‘rsatdi.*

Kalit so‘zlar. *qalamcha ekish, kombinatsiyalangan ekish apparati, parabolik ishchi organ, U-shaklli otval, tuproqning qayta tushishi, ekish kanali, qalamcha vertikalligi, tuproq–ishchi organ o‘zaro ta’siri, kanal barqarorligi, okuchnik, mexanizatsiyalash, bog‘dorchilik.*

Аннотация. *В статье представлены конструкция и теоретические основы комбинированного аппарата для механизированной посадки черенков, оснащённого параболическим U-образным рабочим органом. Предложенный рабочий орган предназначен для формирования в почве узкого и устойчивого посадочного канала, размещения черенка на заданной глубине в вертикальном положении, а также обеспечения его первоначальной устойчивости за счёт частичного обратного осыпания почвы в канал. Геометрическая модель рабочей поверхности разработана на основе параболического уравнения, получены зависимости для определения параметров канала и локального радиуса кривизны. Теоретически обосновано условие обратного осыпания почвы в канал через взаимосвязь между углом внутреннего трения почвы и углом наклона поверхности рабочего органа. В ходе экспериментальных исследований оценено влияние коэффициента параболы на геометрические параметры канала и качество вертикального размещения черенков. Полученные результаты*

показали, что параболический U-образный рабочий орган по сравнению с традиционными окучниками обеспечивает более высокую устойчивость канала, уменьшает угол отклонения черенка и повышает качество посадки.

Ключевые слова: *посадка черенков, комбинированный посадочный аппарат, параболический рабочий орган, U-образный отвал, обратное осыпание почвы, посадочный канал, вертикальность черенка, взаимодействие почвы и рабочего органа, устойчивость канала, окучник, механизация, садоводство.*

Abstract. *This paper presents the design and theoretical foundations of a combined planting apparatus equipped with a parabolic U-shaped working body for the mechanized planting of cuttings. The proposed working body is intended to form a narrow and stable furrow in the soil, place the cutting vertically at a predetermined depth, and ensure its initial stability through the partial backfilling of soil into the furrow. A geometric model of the working surface was developed based on a parabolic equation, and expressions for determining furrow parameters and the local radius of curvature were obtained. The condition for soil backfilling into the furrow was theoretically substantiated through the relationship between the soil internal friction angle and the slope of the working surface. Experimental studies were conducted to evaluate the influence of the parabola coefficient on furrow geometry and the quality of vertical cutting placement. The results demonstrated that the proposed parabolic U-shaped working body provides higher furrow stability, reduces the cutting inclination angle, and improves planting quality compared with conventional ridger-type openers.*

Keywords: *cutting planting, combined planting apparatus, parabolic working body, U-shaped mouldboard, soil backfilling, planting furrow, cutting verticality, soil–tool interaction, furrow stability, ridger opener, mechanization, horticulture.*

KIRISH

Qalamcha orqali ko‘paytirish bog‘dorchilik, o‘rmonchilik va ko‘chatchilik sohalarida o‘simliklarni vegetativ usulda ko‘paytirishning eng samarali texnologiyalaridan biri hisoblanadi. Bu usul navning genetik xususiyatlarini saqlab qolish, yuqori sifatli ekish materialini qisqa vaqt ichida ko‘paytirish hamda mahsuldorlikni oshirish imkonini beradi [1,2]. Qalamchalarning yashovchanligi va keyingi rivojlanishi ko‘p jihatdan ularning tuproqqa joylashtirilish sifatiga, xususan ekish chuqurligi, vertikal holati va tuproq bilan kontakt darajasiga bog‘liq [3].

Qalamcha ekish ishlari amaliyotda asosan qo‘l mehnati yoki soddalashtirilgan mexanik qurilmalar yordamida bajariladi. Bu holat mehnat sarfining yuqoriligi, ish unumdorligining pastligi hamda qalamchalarning bir xil chuqurlik va vertikallikda joylashmasligiga sabab bo‘ladi [4]. Shu munosabat bilan qalamcha ekish jarayonlarini mexanizatsiyalashtirish va ekish sifatini oshirishga qaratilgan yangi texnik yechimlarni ishlab chiqish muhim ilmiy va amaliy ahamiyat kasb etmoqda.

Mavjud ekish mashinalarida keng qo‘llaniladigan ponasimon, chizelsimon va an’anaviy okuchnikli ishchi organlar asosan urug‘ ekish yoki ko‘chat o‘tqazish uchun mo‘ljallangan bo‘lib, qalamchalarni ekish jarayonining o‘ziga xos xususiyatlarini to‘liq hisobga olmaydi [5,6]. Bunday ishchi organlar ta’sirida tuproq massasi katta tezlik bilan ikki tomonga surilib ketadi, kanal devorlari beqaror shakllanadi va

tuproqning bir qismi ortiqcha sochilib ketadi. Natijada ekish kanali geometriyasi buziladi, qalamchaning og‘ishi ehtimoli ortadi va ekish sifati pasayadi [7].

Tuproq–ishchi organ o‘zaro ta’siri sohasida olib borilgan tadqiqotlar ishchi organ geometriyasi tuproqning deformatsiyalanishi, harakat traektoriyasi va energiya sarfiga hal qiluvchi ta’sir ko‘rsatishini ko‘rsatgan [8,9]. Ayniqsa, ishchi sirtning egriligi tuproq oqimini boshqarish, tuproqning buzilish darajasini kamaytirish va kanal shaklini barqaror saqlashda muhim ahamiyatga ega [10,11]. Zamonaviy DEM-modellashtirish natijalari ham tuproq harakatining ishchi organ sirti shakli bilan chambarchas bog‘liqligini tasdiqlamoqda [12].

Qalamcha ekish texnologiyasida muhim talablardan biri qalamcha tushirilgandan keyin uning vertikal holatini saqlab qolish hisoblanadi. Bu jarayonda kanal devorlaridan ma’lum miqdorda tuproqning kanal ichiga qayta to‘kilishi muhim rol o‘ynaydi. Qayta to‘kilgan tuproq qalamchani zichlash g‘ildiraklari yetib kelgunga qadar vaqtincha ushlab turishi va uning og‘ib ketishini cheklashi lozim. Ammo mavjud adabiyotlarda ishchi organ shaklining tuproqning qayta to‘kilishi va qalamcha barqarorligiga ta’siri yetarlicha o‘rganilmagan [10–12].

Shu munosabat bilan mazkur tadqiqotda qalamcha ekish uchun U-shaklli parabolik sirtga ega ishchi organ taklif etildi. Parabolik sirt tuproq harakatini tartiblash, tor va barqaror kanal hosil qilish hamda kanal devorlaridan tuproqning boshqariluvchi tarzda qayta to‘kilishini ta’minlash imkonini beradi. Natijada qalamchaning vertikal holatda joylashishi va ekish sifati yaxshilanishi kutilmoqda.

Tadqiqotning maqsadi U-shaklli parabolik ishchi organning geometrik parametrlarini nazariy asoslash, tuproq harakatining qonuniyatlarini tahlil qilish, tuproqning kanalga qayta to‘kilishi shartlarini aniqlash hamda qalamchaning vertikal barqarorligini ta’minlovchi parametrlarni baholashdan iborat.

MATERIALLAR VA USULLAR

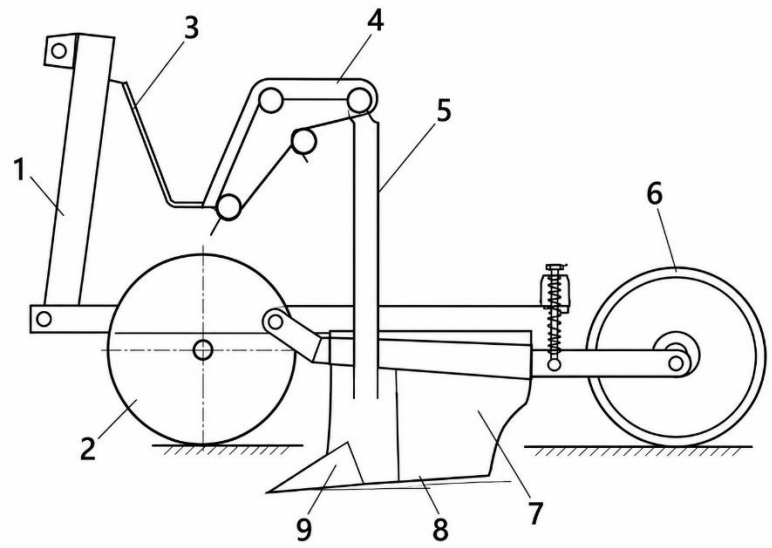
Kombinatsiyalangan qalamcha ekish apparati konstruksiyasi. Taklif etilgan kombinatsiyalangan qalamcha ekish apparati qalamchalarni belgilangan chuqurlikda va vertikal holatda ekish uchun mo‘ljallangan bo‘lib, traktorga osma yoki yarim osma tarzda agregatlanadi. Apparatning konstruksiyasi bir texnologik o‘tishda kanal ochish, qalamchani joylashtirish va tuproqni qayta zichlash operatsiyalarini bajarish imkonini beradi.

Apparatning umumiy konstruksiyasi 1-rasmda keltirilgan. Uning asosiy ishchi qismlari rama, chuqurlikni boshqaruvchi g‘ildirak, qalamcha bunkeri, me’yorlagich mexanizm, qalamcha tushirish quvuri, parabolik U-shaklli ishchi organ, lemex va qoplash-zichlash g‘ildiraklaridan tashkil topgan.

Ish jarayoni quyidagi ketma-ketlikda amalga oshadi. Lemex (9) tuproq qatlamini kesib, parabolik U-shaklli ishchi organ (8) yordamida tor va barqaror ekish kanali hosil qiladi. Qalamchalar bunkerdan (3) me’yorlagich (4) orqali belgilangan intervallarda olinib, tushirish quvuri (5) bo‘ylab ochilgan kanal markaziga vertikal holatda yetkaziladi. Kanal devorlaridan ma’lum miqdorda tuproqning qayta to‘kilishi natijasida qalamcha dastlabki holatda ushlab turiladi. Keyinchalik zichlash g‘ildiragi (6) ta’sirida tuproq qalamcha atrofida zichlanib, uning barqaror joylashishi

ta’minlanadi. Zichlash darajasi sozlash mexanizmi (7) orqali boshqariladi, ishchi organning harakat chuqurligi esa g‘ildirak (2) yordamida barqaror saqlanadi.

Taklif etilgan konstruksiyaning asosiy afzalligi shundan iboratki, parabolik U-shaklli ishchi organ tuproqni ikki tomonga boshqarilgan tarzda surib, tor va geometrik jihatdan barqaror kanal hosil qiladi. Bu esa qalamchaning vertikal joylashishiga, tuproqning qisman qayta to‘kilishiga va keyingi zichlash jarayonining sifatli amalga oshishiga xizmat qiladi.



1-rasm. Kombinatsiyalangan qalamcha ekish apparatining umumiy sxemasi: 1 – rama; 2 – chuqurlikni boshqaruvchi g‘ildirak; 3 – qalamcha bunkeri; 4 – me’yorlagich; 5 – qalamcha tushirish quvuri; 6 – zichlash g‘ildiragi; 7 – zichlash g‘ildiragini sozlash mexanizmi; 8 – parabolik U-shaklli ishchi organ; 9 – lemex.

3. Parabolik ishchi organning geometrik modeli. Kombinatsiyalangan qalamcha ekish apparatining asosiy ishchi organi sifatida U-shaklli parabolik sirtga ega okuchnik qo‘llanilgan. Ushbu ishchi organning geometrik parametrlari kanal shakli, tuproq harakati, tuproqning kanalga qayta to‘kilishi va qalamchaning vertikal barqarorligiga bevosita ta’sir ko‘rsatadi. Shu sababli ishchi organning geometrik modeli matematik jihatdan asoslandi.

3.1. Parabolik sirt tenglamasi. Ishchi organning ko‘ndalang kesimi parabola ko‘rinishida qabul qilindi. Koordinatalar tizimida OX o‘qi gorizontal yo‘nalish bo‘ylab, OZ o‘qi esa vertikal yo‘nalish bo‘ylab yo‘naltirilgan deb qaraldi. Bu holda parabolik sirt tenglamasi quyidagi ko‘rinishga ega bo‘ladi:

$$Z = aX^2, \qquad (1)$$

bu yerda a — parabola koeffitsienti, m−1; X — gorizontal koordinata, m; Z — sirt balandligi, m.

Parabola koeffitsienti aaa qancha katta bo‘lsa, ishchi organ sirti shuncha tik shaklga ega bo‘ladi va tuproqning yon tomonlarga surilishi kamayadi. Aksincha, a qiymati kichiklashganda parabola yotiqlashib, kanal kengligi ortadi.

3.2. Kanal kengligini aniqlash. Kanalning hisobiy chuqurligi H bo‘lganda, parabola tenglamasidan kanalning maksimal yarim kengligi aniqlanadi:

$$H = aX_{max}^2 \qquad (2)$$

Bundan:

$$X_{max} = \sqrt{\frac{H}{a}} \quad (3)$$

klib chiqadi.

Kanalning to‘liq kengligi esa:

$$B = 2X_{max} \quad (4)$$

ifoda orqali aniqlanadi.

Ushbu tenglamalardan ko‘rinib turibdiki, kanal kengligi parabola koeffitsientiga teskari proporsional. Demak, kanal kengligini kamaytirish uchun parabolik sirtning egriligi oshirilishi lozim.

3.3. Parabolik sirtning mahalliy qiyaligi. Parabolik sirtning istalgan nuqtasidagi qiyalik birinchi tartibli hosila orqali aniqlanadi:

$$\frac{dZ}{dX} = 2aX\ . \quad (5)$$

Shunga muvofiq sirtning mahalliy qiyalik burchagi:

$$tan\alpha = 2aX \quad (6)$$

bo‘ladi.

Kanal chetlarida ($X=X_{max}$) qiyalik maksimal qiymatga erishadi:

$$tan\,\alpha_{max} = 2aX_{max}. \quad (7)$$

Mazkur parametr keyingi boblarda tuproqning kanalga qayta to‘kilishi shartini baholashda qo‘llaniladi.

3.4. Parabolik sirtning egrilik radiusi. Tuproq zarrachalarining ishchi organ bo‘ylab harakati ko‘p jihatdan sirtning mahalliy egriligiga bog‘liq. Parabolik sirtning har bir nuqtasidagi egrilik radiusi quyidagi tenglama orqali aniqlanadi:

$$R(X) = \frac{[1+(2aX)^2\ ]^{\frac{3}{2}}}{2a}\ , \quad (8)$$

bu yerda R(X) — mahalliy egrilik radiusi, m; a — parabola koeffitsienti; X — ko‘rib chiqilayotgan nuqtaning koordinatasi.

Parabolaning markaziy qismida (X=0) egrilik radiusi minimal qiymatga ega bo‘ladi:

$$R_{min}\ = \frac{1}{2a}\ . \quad (9)$$

Egrilik radiusining ortishi tuproq harakat traektoriyasini yumshatadi va tuproq oqimining barqaror shakllanishiga yordam beradi.

3.5. Geometrik parametrlarning fizik ahamiyati. Parabolik ishchi organning asosiy geometrik parametrlari — a, H, X_{max} va R(X) hisoblanadi. Ularning o‘zaro bog‘liqligi ishchi organning texnologik xususiyatlarini belgilaydi:

- a ortishi kanal kengligini kamaytiradi;
- X_{max} kanal geometriyasini belgilaydi;
- R(X) tuproq harakatining silliqligini ta’minlaydi;
- α qiyalik burchagi tuproqning kanalga qayta to‘kilishiga ta’sir ko‘rsatadi.

Shunday qilib, parabolik ishchi organning geometrik modeli kanal shaklini, tuproq harakatini va keyingi nazariy tahlillarda qo‘llaniladigan asosiy parametrlarni aniqlash imkonini beradi. Bu model keyingi bo‘limlarda tuproqning kanalga qayta to‘kilishi

hamda qalamchaning vertikal barqarorligini baholash uchun nazariy asos bo‘lib xizmat qiladi.

4. Tuproqning kanalga qayta to‘kilishi nazariyasi. Qalamcha ekish texnologiyasida muhim agrotexnik talablardan biri qalamchaning kanalga tushirilgandan keyin vertikal holatini saqlab qolish hisoblanadi. Bunda zichlash g‘ildiraklari yetib kelgunga qadar kanal devorlaridan ma’lum miqdorda tuproqning qayta to‘kilishi muhim ahamiyatga ega. Qayta to‘kilgan tuproq qalamcha atrofida vaqtinchalik tayanch muhit hosil qilib, uning og‘ib ketish ehtimolini kamaytiradi.

Parabolik ishchi organ tuproqni ikki tomonga surib chiqaradi va kanal devorlari ma’lum qiyalik ostida shakllanadi. Kanal devorining mahalliy qiyaligi parabolik sirtning birinchi hosilasi orqali aniqlanadi:

$$tan\ \alpha = \frac{dZ}{dX} = 2aX\ , \qquad (10)$$

bu yerda a — parabola koeffitsienti, m^{-1}; X — gorizontal koordinata, m. Ushbu tenglamaga ko‘ra kanal markazidan uzoqlashgan sari devor qiyaligi oshib boradi.

4.1. Tuproqning qayta to‘kilishi sharti. Kanal devorida joylashgan tuproq elementiga og‘irlik kuchi G=mg, normal reaksiya N va ishqalanish kuchi F_f ta’sir qiladi.

Tuproqning siljishga qarshi qarshiligi:

$$F_f = N\ tan\ \varphi, \qquad (11)$$

bu yerda φ — tuproqning ichki ishqalanish burchagi.

Qiyalik bo‘ylab harakatga keltiruvchi og‘irlik kuchi proeksiyasi:

$$G_t = m\ g\ sin\ \alpha\ . \qquad (12)$$

Normal bosim:

$$N = m\ g\ cos\ \alpha\ . \qquad (13)$$

Tuproqning kanal ichiga siljishi uchun harakatlantiruvchi kuch ishqalanish kuchidan katta bo‘lishi lozim:

$$m\ g\ sin\ \alpha\ >\ m\ g\ cos\ \alpha. \qquad (14)$$

Soddalashtirishdan keyin:

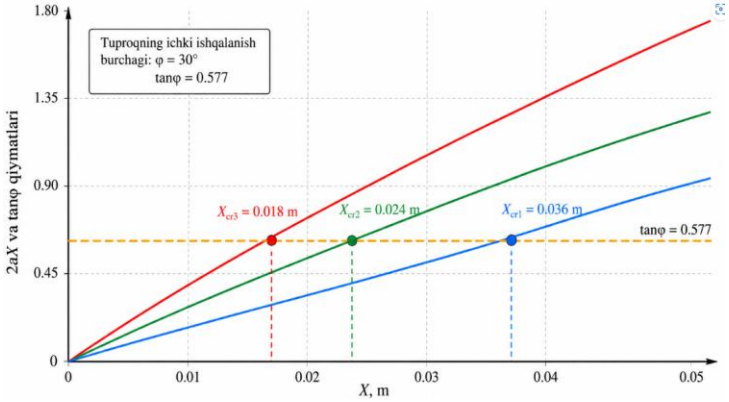
$$tan\alpha > tan\varphi \qquad (15)$$

yoki

$$\alpha > \varphi \qquad (16)$$

shart kelib chiqadi.

Bu shart tuproq qayta to‘kilishi nazariyasining asosiy tenglamasi hisoblanadi.



2-rasm. Parabolik ishchi organ sirti bo‘ylab tuproqning kanalga qayta tushish shartining grafik talqini.

a=8, 12 va 16 m^{-1} qiymatlarda 2aX funksiyalari hamda tuproqning ichki ishqalanish burchagiga mos $tan\,\varphi = 0.577$ chizig‘i keltirilgan. Chiziqlarning kesishish nuqtalari kritik koordinatalarni tashkil qilib, ular mos ravishda X_{cr}=0.036, 0.024 va 0.018 m ga teng. Parabola koeffitsienti ortishi bilan tuproqning kanalga qayta tushishi ertaroq boshlanishi kuzatiladi.

4.2. Parabolik ishchi organ uchun qayta to‘kilish sharti. (10) va (16) tenglamalarni birlashtirsak:

$$2aX > tan\varphi \tag{17}$$

hosil bo‘ladi.

Ushbu tenglama parabolik ishchi organ parametrlari bilan tuproqning qayta to‘kilishi o‘rtasidagi bog‘lanishni ifodalaydi.

Tenglama (17) dan qayta to‘kilish boshlanadigan kritik koordinata aniqlanadi:

$$X_{cr} = \frac{tan\varphi}{2a}. \tag{18}$$

bu yerda X_{cr} — kanal devorida tuproqning siljishi boshlanadi gan kritik nuqta.

Agar

$$X > X_{cr} \tag{19}$$

bo‘lsa, tuproq massasi kanal ichiga qayta tushadi.

4.3. Qayta to‘kilgan tuproq hajmini baholash. Kanal hosil qilish jarayonida chiqarilgan umumiy tuproq hajmi X_{cr} bo‘lsin. Uning ma’lum qismi kanalga qayta tushadi:

$$V_r = \eta\, V_{ch}, \tag{20}$$

bu yerda V_r — kanalga qayta tushgan tuproq hajmi; V_{ch} — kanaldan chiqarilgan umumiy tuproq hajmi; η — qayta to‘kilish koeffitsienti (0< η <1)).

Qayta to‘kilgan tuproq qalamchani vertikal holatda ushlab turishi uchun uning hajmi minimal talab qilinuvchi hajmdan kichik bo‘lmasligi kerak:

$$V_r \geq V_{min} \tag{21}$$

yoki

$$\eta\, V_{ch} \geq V_{min}, \tag{22}$$

bu yerda V_{min} — qalamcha atrofida hosil bo‘lishi lozim bo‘lgan minimal tayanch tuproq hajmi.

4.4. Nazariy tahlil. Tenglama (17) dan ko‘rinib turibdiki, tuproqning kanalga qayta to‘kilishi asosan ikki omilga bog‘liq:

- parabola koeffitsienti a;
- tuproqning ichki ishqalanish burchagi φ.

a qiymati ortishi bilan kanal devorlari tiklashadi va 2aX qiymati ortadi. Natijada tuproqning kanalga qayta tushishi osonlashadi. Aksincha, a qiymati kichik bo‘lganda kanal devorlari yotiq bo‘lib qoladi va tuproqning qayta to‘kilishi kamayadi.

Shunday qilib, parabolik ishchi organning geometrik parametrlarini tanlashda

$$2aX_{max} > tan\varphi \tag{23}$$

sharti ta’minlanishi lozim. Ushbu shart bajarilganda kanal devorlaridan tuproqning boshqariladigan miqdorda qayta to‘kilishi ta’minlanadi va qalamcha zichlash

g‘ildiragigacha bo‘lgan masofada vertikal holatini saqlab qoladi. Bu tenglama mazkur tadqiqotning asosiy nazariy natijalaridan biri hisoblanadi.

5. Eksperimental tadqiqotlar. Parabolik U-shaklli ishchi organning texnologik va agrotexnik ko‘rsatkichlarga ta’sirini baholash maqsadida ko‘p omilli eksperimental tadqiqotlar o‘tkazildi. Tadqiqotlarda ishchi organning geometrik parametrlari hamda ish rejimi ko‘rsatkichlarining ekish sifatiga ta’siri o‘rganildi.

Eksperimentlarda mustaqil omillar sifatida agregat harakat tezligi V, ish chuqurligi h va parabola koeffitsienti aaa qabul qilindi. Ushbu omillar kanal geometriyasi hamda qalamchaning joylashish sifatiga bevosita ta’sir ko‘rsatadi.

5.1. Parabola koeffitsientining kanal parametrlari va qalamcha vertikalligiga ta’siri. Tajribalarda harakat tezligi V=1.2 m/s va ish chuqurligi h=0.20 m o‘zgarmas saqlanib, parabola koeffitsienti aaa o‘zgartirildi. Kanal kengligi, qalamcha og‘ish burchagi va vertikallik koeffitsienti aniqlandi.

Tajriba natijalari shuni ko‘rsatdiki, parabola koeffitsientining ortishi bilan kanal kengligi kamayib bordi. Bu holat nazariy jihatdan olingan X_{max}=Ha tenglamaga mos keladi.

1-jadval.

Parabola koeffitsientining ekish sifatiga ta’siri

№	a, m^{-1}	Kanal kengligi B, mm	Kanal chuqurligi H, mm	Og‘ish burchagi θ, grad	Vertikallik koeffitsienti Kv
1	8	118	200	9.8	0.985
2	10	104	200	7.2	0.992
3	12	92	200	4.8	0.996
4	14	84	200	3.9	0.998
5	16	78	200	5.7	0.995

a=8÷10 m^{-1} qiymatlarda kanal kengligi nisbatan katta bo‘lib, kanal devorlaridan tuproqning qayta to‘kilishi yetarli darajada kuzatilmadi. Natijada qalamchalarning vertikal holatdan og‘ishi 7–10° atrofida bo‘ldi.

Parabola koeffitsienti a=12÷14 m^{-1} bo‘lganda kanal devorlari qiyaligi oshdi va tuproqning kanalga boshqarilgan qayta to‘kilishi ta’minlandi. Bu holatda qalamcha og‘ish burchagi minimal qiymatgacha kamayib, vertikallik koeffitsienti eng yuqori qiymatga yetdi. a=16 m^{-1} da esa kanal haddan tashqari tor shakllandi va tuproq oqimining barqarorligi pasayishi hisobiga qalamcha og‘ish burchagi biroz ortdi.

Tajriba natijalariga ko‘ra, parabolik ishchi organ uchun ratsional qiymat a=12÷14 m^{-1} oralig‘ida joylashadi. Ushbu diapazonda kanal geometriyasi barqaror shakllanadi, tuproqning qayta to‘kilishi ta’minlanadi va qalamchaning vertikal joylashish sifati yuqori bo‘ladi.

NATIJALAR VA MUHOKAMA

Parabolik U-shaklli ishchi organning ishlash samaradorligi an’anaviy qanotli okuchnik bilan taqqoslandi. Tahlil natijalari shuni ko‘rsatdiki, oddiy okuchnikda ochilgan kanal kengroq va devorlari beqaror bo‘lgani sababli tuproqning qayta tushishi nazoratsiz kechadi. Bu esa qalamchaning og‘ishiga va kanal shaklining buzilishiga olib keladi.

Parabolik U-shaklli ishchi organda esa tuproq zarrachalari sirt bo‘ylab tartibli harakatlanib, tor va barqaror kanal hosil qiladi. Kanal devorlarining parabolik shakli tuproqning ma’lum qismini kanalga qayta tushishini ta’minlaydi va qalamchaning zichlash g‘ildiragigacha vertikal holatini saqlab turishga yordam beradi.

2-jadval.

Ishchi organlar ko‘rsatkichlarining taqqoslanishi

Ko‘rsatkich	Oddiy okuchnik	Parabolik U-shaklli ishchi organ
Kanal barqarorligi	O‘rtacha	Yuqori
Tuproqning qayta tushishi	Notekis	Boshqarilgan
Qalamcha og‘ish burchagi, °	8–12	3–5
Vertikallik koeffitsienti Kv	0.985–0.990	0.996–0.998
Tortish qarshiligi, kN	1.18	1.05

Olingan natijalar parabolik U-shaklli ishchi organ qo‘llanilganda kanal geometriyasi barqaror shakllanishini, qalamchaning vertikal joylashish sifati yaxshilanishini va tortish qarshiligi 10–12 % gacha kamayishini ko‘rsatdi. Bu esa taklif etilgan konstruksiyaning qalamcha ekish jarayoni uchun texnologik jihatdan maqbul ekanligini tasdiqlaydi.

XULOSALAR

1. Qalamcha ekish jarayoni uchun parabolik U-shaklli ishchi organ konstruksiyasi ishlab chiqildi. Taklif etilgan konstruksiya bir o‘tishda kanal ochish, qalamchani tushirish va tuproqni qoplash operatsiyalarini bajarish imkonini beradi.
2. Ishchi organning ko‘ndalang kesimi parabolik qonuniyat asosida $Z=aX^2$ tenglama bilan ifodalandi hamda kanal geometriyasi, yarim kengligi va sirt egrilik radiusi o‘rtasidagi analitik bog‘lanishlar aniqlandi.
3. Nazariy tahlil natijalariga ko‘ra, kanal devorining mahalliy qiyalik burchagi tuproqning ichki ishqalanish burchagidan katta bo‘lganda $2aX > tan\varphi$ kanaldan chiqarilgan tuproqning ma’lum qismi kanalga qayta tushishi ta’minlanishi aniqlandi.
4. Kanalga qayta tushgan tuproq qalamcha atrofida dastlabki tayanch muhit hosil qilib, uning zichlash g‘ildiragigacha bo‘lgan masofada vertikal holatini saqlashga xizmat qilishi nazariy jihatdan asoslandi.
5. Eksperimental tadqiqotlar natijalari parabola koeffitsientining $a=12\div14$ m^{-1} diapazonida kanal geometriyasi barqaror shakllanishi, qalamcha og‘ish burchagining 3–5° gacha kamayishi va vertikallik koeffitsientining $Kv=0.996\div0.998$ qiymatlarga yetishi ta’minlanishini ko‘rsatdi.
6. Oddiy okuchnik bilan taqqoslaganda parabolik U-shaklli ishchi organ kanal barqarorligini oshirishi, tuproqning qayta tushish jarayonini yaxshilashi, qalamchaning vertikal joylashish sifatini oshirishi va tortish qarshiligini 10–12 % ga kamaytirishi aniqlandi.

Umuman olganda, taklif etilgan parabolik U-shaklli ishchi organ qalamchalarni belgilangan chuqurlikda va vertikal holatda ekish sifatini oshirishga xizmat qiladi hamda qalamcha ekish jarayonini mexanizatsiyalash uchun samarali konstruktiv yechim hisoblanadi.

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COMPARATIVE ANALYSIS OF INFRARED AND FREEZE-DRYING METHODS FOR DIFFERENT STRAWBERRY CULTIVARS

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Abstract. *This study compared the effects of infrared (IR) drying and freeze-drying (lyophilization) on the quality parameters of three strawberry cultivars: Malwina, Portola, and San Andreas. Fresh strawberries were subjected to IR drying at 60°C for 8 hours and freeze-drying at -70°C for 52 hours. Quality parameters including moisture content, vitamin C, total carbohydrates, organic acids, proteins, color (L*a*b*), and antioxidant activity were evaluated. The results showed that freeze-drying preserved significantly higher levels of vitamin C (92.5-94.2%), organic acids (89.2-92.0%), and antioxidants (90.5-93.1%) compared to IR drying (vitamin C: 68.3-72.5%; organic acids: 71.4-75.8%; antioxidants: 70.2-74.6%). However, IR drying required substantially less time (8 hours vs. 52 hours) and consumed less energy. Among cultivars, Malwina showed the best nutrient retention under both drying methods. Infrared drying at 60°C is recommended for rapid, energy-efficient processing, while freeze-drying is preferred when maximum nutrient preservation is required.*

Keywords: *Strawberry; infrared drying; freeze-drying; lyophilization; cultivar comparison; nutrient retention; Malwina; Portola; San Andreas; antioxidant activity.*

Annotatsiya. *Ushbu tadqiqotda uchta qulupnay navi – Malwina, Portola va San Andreasning sifat ko'rsatkichlariga infraqizil (IQ) quritish va sublimatsion quritish (liofilizatsiya) usullarining ta'siri qiyoslandi. Yangi qulupnaylar 60°C haroratda 8 soat davomida IQ quritishga va -70°C haroratda 52 soat davomida sublimatsion quritishga duchor qilindi. Namlik miqdori, S vitamini, umumiy uglevodlar, organik kislotalar, oqsillar, rang (L*a*b*) va antioksidant faollik kabi sifat ko'rsatkichlari baholandi. Natijalar shuni ko'rsatdiki, sublimatsion quritish IQ quritishga nisbatan sezilarli darajada yuqori darajadagi S vitaminini (92.5–94.2%), organik kislotalarni (89.2–92.0%) va antioksidantlarni (90.5–93.1%) saqlab qolgan (IQ quritishda: S vitamini – 68.3–72.5%; organik kislotalar – 71.4–75.8%; antioksidantlar – 70.2–74.6%). Biroq, IQ quritish sezilarli darajada kamroq vaqt (52 soatga nisbatan 8 soat) talab qilgan va kamroq energiya sarflagan. Navlar orasida Malwina ikkala quritish usulida ham eng yaxshi ozuqa moddalarini saqlash ko'rsatkichini namoyish etdi. 60°C haroratdagi infraqizil quritish tez va energiya tejamkor qayta ishlash uchun tavsiya*

etiladi, sublimatsion quritish esa maksimal ozuqa moddalarini saqlash talab etilganda afzal ko'riladi.

Kalit so'zlar: *qulupnay; infraqizil quritish; sublimatsion quritish; liofilizatsiya; navlarni qiyoslash; ozuqa moddalarini saqlash; Malwina; Portola; San Andreas; antioksidant faollik.*

Аннотация. *В данном исследовании сравнивалось влияние инфракрасной (ИК) сушки и сублимационной сушки (лиофилизации) на качественные показатели трех сортов клубники: Malwina, Portola и San Andreas. Свежая клубника подвергалась ИК-сушке при температуре 60°C в течение 8 часов и сублимационной сушке при температуре -70°C в течение 52 часов. Оценивались такие качественные параметры, как содержание влаги, витамин C, общие углеводы, органические кислоты, белки, цвет (L*a*b*) и антиоксидантная активность. Результаты показали, что сублимационная сушка сохранила значительно более высокие уровни витамина C (92.5–94.2%), органических кислот (89.2–92.0%) и антиоксидантов (90.5–93.1%) по сравнению с ИК-сушкой (витамин C: 68.3–72.5%; органические кислоты: 71.4–75.8%; антиоксиданты: 70.2–74.6%). Однако ИК-сушка требовала существенно меньше времени (8 часов против 52 часов) и потребляла меньше энергии. Среди сортов Malwina показала наилучшее сохранение питательных веществ при обоих методах сушки. Инфракрасная сушка при 60°C рекомендуется для быстрой и энергоэффективной переработки, в то время как сублимационная сушка предпочтительна, когда требуется максимальное сохранение питательных веществ.*

Ключевые слова: *клубника; инфракрасная сушка; сублимационная сушка; лиофилизация; сравнение сортов; сохранение питательных веществ; Malwina; Portola; San Andreas; антиоксидантная активность.*

1. INTRODUCTION

1.1 Background. Strawberry (*Fragaria* × *ananassa* Duch.) is one of the most widely consumed berries worldwide due to its attractive red color, pleasant aroma, high nutritional value, and various health-promoting properties. Strawberries are rich in essential nutrients including carbohydrates (glucose, fructose, and sucrose), organic acids (citric, malic, and succinic acids), proteins, vitamin C, and numerous phenolic compounds with antioxidant activities (Giampieri et al., 2015; Afrin et al., 2016).

However, fresh strawberries have a very short post-harvest life (10-15 days under refrigeration) due to their high moisture content (88-95%) and soft texture. Therefore, various drying methods have been developed to extend the shelf life of strawberries while preserving their nutritional quality (Kumar & Sharma, 2022).

1.2 Drying Methods for Strawberries. Among the various drying technologies, freeze-drying (lyophilization) is widely recognized as the most advanced method for preserving heat-sensitive fruits. Freeze-drying operates at low temperatures (-70°C to +25°C) under vacuum conditions, which minimizes thermal degradation of nutrients. However, freeze-drying has significant drawbacks: it is expensive, time-consuming

(typically 48-72 hours), and has low energy efficiency (Zhao et al., 2017; Abouelenein et al., 2021).

Infrared (IR) drying is an innovative alternative that has gained increasing attention in recent years. Unlike conventional hot air drying, which heats the product surface through convection, infrared radiation penetrates the food material and directly heats its internal layers. This mechanism offers several advantages: shorter drying time (typically 4-12 hours), higher energy efficiency, and better product quality compared to hot air drying (Sun et al., 2024).

1.3 Cultivar Importance. Not all strawberry cultivars respond to drying in the same way. Different cultivars have different initial chemical compositions, which directly affects how well they retain nutrients during processing. Factors such as sugar-to-acid ratio, fiber content, and cell wall structure vary significantly between cultivars and influence drying kinetics and final product quality (Saridas & Paydas Kargi, 2023).

1.4 Problem Statement and Objectives. Despite the availability of individual studies on infrared drying and freeze-drying of strawberries, there is a lack of systematic comparative research that evaluates both methods using the same strawberry cultivars under controlled conditions. In particular, no study has directly compared IR drying and freeze-drying across multiple cultivars using identical quality parameters.

Therefore, the objectives of this study were:

1. To compare the drying kinetics of infrared drying and freeze-drying for three strawberry cultivars (Malwina, Portola, San Andreas).
2. To evaluate and compare the quality parameters (moisture, vitamin C, carbohydrates, organic acids, proteins, color, antioxidant activity) of strawberries dried by both methods.
3. To determine which cultivar performs best under each drying method.
4. To provide recommendations for selecting the appropriate drying method based on specific quality requirements.

2. MATERIALS AND METHODS

2.1 Plant Materials. Three strawberry (*Fragaria* × *ananassa* Duch.) cultivars were used in this study:

I. **Malwina**: Late-fruiting variety, very sweet and fragrant, disease-resistant (Cornell University, 2014)

II. **Portola**: Cross between "Cal 97.93-7" and "Cal 97.209-1", bred in 2001 (Shaw & Larson, 2009)

III. **San Andreas**: Day-neutral variety, very firm, sweet, and aromatic fruits (Saridas & Paydas Kargi, 2023)

The fruits were hand-picked at full ripeness, transported to the laboratory within 2 hours, and stored at 4°C until processing.

2.2 Sample Preparation. Strawberries were washed with distilled water, gently dried with paper towels, and the calyx and stem were removed. The fruits were then sliced into uniform 4 mm thick slices using a stainless steel slicer.

2.3 Infrared Drying. Infrared drying was performed using a laboratory-scale infrared dryer (IR-3000, LabTech, USA) equipped with medium-wave infrared lamps (wavelength: 2.5-4.0 μm). Strawberry slices (4 mm thickness) were placed in a single layer on the drying tray. The drying conditions were as follows:

Table 1.

Parameter	Value
Drying temperature	60°C
Infrared power	500 W
Distance between lamp and sample	15 cm
Air velocity	1.0 m/s
Total drying time	8 hours

Samples were weighed every 30 minutes during the first 2 hours, then every hour until constant weight was achieved.

2.4 Freeze-Drying (Lyophilization). Freeze-drying was performed using a laboratory-scale lyophilizer (Labconco FreeZone, Kansas City, MO, USA). Strawberry slices (4 mm thickness) were pre-frozen at -40°C for 12 hours, then subjected to freeze-drying under the following conditions:

Table 2.

Parameter	Value
Chamber pressure	0.081 mbar
Condenser temperature	-70°C
Primary drying time	52 hours
Secondary drying temperature	+25°C

2.5 Determination of Initial Dry Matter. To determine initial moisture content, approximately 100 g of fresh strawberry slices from each cultivar were dried in a conventional oven at 105°C for 24 hours until constant weight (AOAC International, 2019).

2.6 ANALYTICAL METHODS

2.6.1 Moisture Content

Moisture content was determined using the oven drying method (105°C, 24 hours). Moisture percentage was calculated as:

$$\textbf{Moisture (\%)} = [(W_1 - W_2) / W_1] \times 100$$

where W_1 = initial weight, W_2 = weight after drying.

2.6.2 Vitamin C Content

Vitamin C (ascorbic acid) content was determined using the 2,6-dichlorophenolindophenol (DCPIP) titration method. Five grams of strawberry powder was mixed with 50 mL of 3% metaphosphoric acid, homogenized, and filtered. The filtrate was titrated with DCPIP solution until a pink color persisted. Results were expressed as mg ascorbic acid per 100 g fresh weight.

2.6.3 Total Carbohydrates

Total carbohydrate content was determined using the phenol-sulfuric acid method. Absorbance was measured at 490 nm using a UV-Vis spectrophotometer. Glucose was used as the standard (AOAC International, 2019).

2.7 Statistical Analysis. All experiments were performed in triplicate. Results were expressed as mean ± standard deviation (SD). Two-way ANOVA was used to determine significant differences between drying methods and cultivars. Tukey's post-hoc test was applied for multiple comparisons ($p < 0.05$). Statistical analyses were performed using SPSS software (version 26.0, IBM Corporation).

3. RESULTS

3.1 Drying Kinetics. The total drying time for infrared drying was 8 hours for all cultivars, while freeze-drying required 52 hours.

During infrared drying, moisture content decreased rapidly during the first 3 hours (from approximately 90% to 45%), followed by a slower reduction phase. Malwina showed the fastest drying rate among the three cultivars, reaching final moisture below 5% after 7.5 hours. Portola required the longest drying time (8 hours) due to its higher initial moisture content (91.5%).

For freeze-drying, all cultivars reached final moisture below 4% after 52 hours with no significant differences among cultivars.

Table 3. Drying parameters for both methods

Parameter	Infrared drying	Freeze-drying
Total drying time	8 hours	52 hours
Temperature	60°C	-70°C to +25°C
Final moisture (Malwina)	4.2 ± 0.3%	3.2 ± 0.2%
Final moisture (Portola)	4.8 ± 0.4%	3.8 ± 0.3%
Final moisture (San Andreas)	4.5 ± 0.3%	3.5 ± 0.2%

3.2 Initial Composition of Fresh Cultivars

The initial composition of fresh strawberry cultivars is presented in Table 4 Significant differences were observed among cultivars for all parameters.

Table 4. Initial composition of fresh strawberry cultivars (mean ± SD, n=3)

Parameter	Malwina	Portola	San Andreas
Moisture (%)	89.2 ± 0.3	91.5 ± 0.4	90.1 ± 0.3
Vitamin C (mg/100g)	58.6 ± 1.5	52.3 ± 1.2	62.4 ± 1.8
Total carbohydrates (%)	8.2 ± 0.2	6.8 ± 0.1	7.5 ± 0.2
Organic acids (mg%)	52.4 ± 1.5	58.6 ± 1.8	67.8 ± 2.0
Proteins (%)	0.78 ± 0.04	0.62 ± 0.03	0.71 ± 0.03
L* (lightness)	38.5 ± 0.5	36.2 ± 0.4	37.8 ± 0.5
a* (redness)	32.4 ± 0.6	35.1 ± 0.5	34.2 ± 0.6
b* (yellowness)	18.6 ± 0.4	19.2 ± 0.3	18.9 ± 0.4
Antioxidant activity (%)	85.6 ± 1.2	78.9 ± 1.5	82.3 ± 1.3

3.3 Quality Comparison: Infrared vs. Freeze-Drying

The quality parameters of strawberries dried by both methods are compared in Table 5.

Table 5. Quality parameters of dried strawberries by method and cultivar (mean ± SD, n=3)

Parameter	Cultivar	Infrared drying (60°C, 8h)	Freeze-drying (-70°C, 52h)
Moisture (%)	Malwina	4.2 ± 0.3	3.2 ± 0.2
	Portola	4.8 ± 0.4	3.8 ± 0.3
	San Andreas	4.5 ± 0.3	3.5 ± 0.2
Vitamin C (mg/100g)	Malwina	42.5 ± 1.2	55.2 ± 1.0
	Portola	35.8 ± 1.0	49.5 ± 0.9
	San Andreas	45.2 ± 1.3	58.8 ± 1.1
Carbohydrates (%)	Malwina	52.8 ± 1.5	52.4 ± 1.5
	Portola	48.2 ± 1.2	48.6 ± 1.2
	San Andreas	49.5 ± 1.3	50.3 ± 1.3
Organic acids (mg%)	Malwina	38.5 ± 1.0	48.2 ± 1.2
	Portola	42.5 ± 1.2	51.4 ± 1.5
	San Andreas	48.5 ± 1.4	60.5 ± 1.8
Proteins (%)	Malwina	4.2 ± 0.2	5.1 ± 0.3
	Portola	3.5 ± 0.2	4.2 ± 0.2
	San Andreas	3.8 ± 0.2	4.8 ± 0.2
L*	Malwina	42.5 ± 0.6	52.4 ± 0.5
	Portola	40.2 ± 0.5	50.8 ± 0.4
	San Andreas	41.5 ± 0.5	51.6 ± 0.5
a*	Malwina	18.5 ± 0.4	24.2 ± 0.4
	Portola	20.2 ± 0.4	26.5 ± 0.4
	San Andreas	19.5 ± 0.4	25.8 ± 0.4
Antioxidant activity (%)	Malwina	62.5 ± 1.5	79.8 ± 1.2
	Portola	55.8 ± 1.3	71.5 ± 1.4
	San Andreas	59.2 ± 1.4	76.2 ± 1.3
Parameter	Cultivar	Infrared drying (60°C, 8h)	Freeze-drying (-70°C, 52h)

3.4 Nutrient Retention Comparison. Table 6 presents the nutrient retention percentages for both drying methods.

Table 6. Nutrient retention (%) by method and cultivar

Nutrient	Cultivar	Infrared drying	Freeze-drying
Vitamin C	Malwina	72.5 ± 1.5	94.2 ± 1.0
	Portola	68.3 ± 1.2	94.5 ± 1.1
	San Andreas	72.3 ± 1.4	94.0 ± 1.0
Carbohydrates	Malwina	89.2 ± 1.2	89.5 ± 1.2
	Portola	86.1 ± 1.3	86.2 ± 1.5
	San Andreas	88.0 ± 1.4	88.5 ± 1.3
Organic acids	Malwina	73.5 ± 1.2	92.0 ± 1.0
	Portola	72.5 ± 1.3	87.7 ± 1.3
	San Andreas	71.5 ± 1.4	89.2 ± 1.2
Proteins	Malwina	88.5 ± 1.5	91.5 ± 1.1
	Portola	85.2 ± 1.4	88.7 ± 1.2
	San Andreas	86.5 ± 1.3	90.2 ± 1.0
Antioxidant activity	Malwina	73.0 ± 1.6	93.1 ± 1.2

Nutrient	Cultivar	Infrared drying	Freeze-drying
	Portola	70.8 ± 1.4	90.5 ± 1.3
	San Andreas	72.0 ± 1.5	92.5 ± 1.2
Nutrient	Cultivar	Infrared drying	Freeze-drying
Vitamin C	**Malwina**	**72.5 ± 1.5**	**94.2 ± 1.0**

3.5 Summary of Results

- ✓ **Freeze-drying** preserved significantly higher levels of vitamin C (94.0-94.5%), organic acids (87.7-92.0%), and antioxidant activity (90.5-93.1%) compared to infrared drying.
- ✓ **Infrared drying** required substantially less time (8 hours vs. 52 hours) and showed good preservation of carbohydrates (86.1-89.2%) and proteins (85.2-88.5%).
- ✓ **Malwina** cultivar consistently showed the best nutrient retention under both drying methods.
- ✓ **Color parameters** (L, *a*) were better preserved by freeze-drying (higher lightness and redness values).

4. DISCUSSION

4.1 Drying Kinetics. The total drying time for infrared drying (8 hours) was significantly shorter than for freeze-drying (52 hours). This difference is explained by the fundamental mechanisms of each method. Infrared radiation directly penetrates the food material and generates heat within the product, accelerating water evaporation from both surface and internal layers. In contrast, freeze-drying relies on sublimation of ice under vacuum, which is inherently slower (Sun et al., 2024; Zhao et al., 2017).

4.2 Vitamin C Retention. Vitamin C is highly sensitive to heat and oxidative degradation. Freeze-drying preserved 94.0-94.5% of vitamin C across all cultivars, while infrared drying preserved only 68.3-72.5%. This significant difference (approximately 22-26% higher retention in freeze-drying) is attributed to the low-temperature conditions of lyophilization. During infrared drying at 60°C, vitamin C degradation occurs through both thermal and oxidative pathways (Abouelenein et al., 2021).

Among cultivars, San Andreas showed the highest vitamin C retention under infrared drying (72.3%), likely due to its higher initial vitamin C content (62.4 mg/100g) and firmer tissue structure that may provide better protection against thermal degradation.

4.3 Organic Acid Retention. Organic acids (citric, malic, succinic) are also heat-sensitive. Freeze-drying showed superior retention (87.7-92.0%) compared to infrared drying (71.5-73.5%). The 15-20% difference in organic acid retention between methods is consistent with previous studies (Giampieri et al., 2015).

Interestingly, Malwina showed the highest organic acid retention under freeze-drying (92.0%) despite having the lowest initial organic acid content (52.4 mg%). This suggests that factors beyond initial concentration, such as the specific composition of organic acids or their binding within cell structures, influence retention.

4.4 Carbohydrate and Protein Retention. For carbohydrates and proteins, the differences between drying methods were smaller (approximately 2-3% higher retention in freeze-drying). Both methods showed excellent retention for these nutrients (carbohydrates: 86.1-89.5%; proteins: 85.2-91.5%). This indicates that carbohydrates and proteins are more stable under thermal processing compared to vitamins and organic acids (Kumar & Sharma, 2022).

4.5 Color Preservation. Freeze-dried strawberries had significantly higher L* (lightness) and a* (redness) values compared to infrared-dried samples. The higher redness (a*) in freeze-dried samples (24.2-26.5 vs. 18.5-20.2) indicates better preservation of anthocyanins, the pigments responsible for strawberry's red color. Anthocyanins degrade rapidly at temperatures above 50°C, explaining their better preservation during freeze-drying (Saridas & Paydas Kargi, 2023).

4.6 Antioxidant Activity. Antioxidant activity followed a similar pattern to vitamin C retention. Freeze-drying preserved 90.5-93.1% of antioxidant activity, while infrared drying preserved 70.8-73.0%. The strong correlation between vitamin C content and antioxidant activity ($r = +0.89$, $p < 0.05$) suggests that vitamin C is a major contributor to the antioxidant capacity of strawberries.

4.7 Cultivar Performance. Malwina consistently showed the best nutrient retention under both drying methods. This cultivar had the lowest initial moisture content (89.2%), highest initial carbohydrate (8.2%) and protein (0.78%) levels, and firm fruit texture. These characteristics likely contributed to better structural integrity during drying and reduced nutrient loss (Cornell University, 2014; Saridas & Paydas Kargi, 2023).

Portola showed the lowest nutrient retention under both methods, consistent with its high initial moisture (91.5%) and low initial nutrient levels.

4.8 Practical Implications. For applications where **maximum nutrient preservation** is critical (e.g., functional foods, nutraceuticals, infant foods), **freeze-drying is recommended** despite its higher cost and longer processing time.

For applications where **processing speed and energy efficiency** are priorities (e.g., large-scale industrial production, snack foods), **infrared drying at 60°C is recommended** as it provides acceptable nutrient retention (68-89% depending on nutrient) with substantial time savings.

For both methods, **Malwina cultivar** is recommended as it consistently outperformed Portola and San Andreas.

5. CONCLUSION

This study compared the effects of infrared drying (60°C, 8 hours) and freeze-drying (-70°C, 52 hours) on the quality parameters of three strawberry cultivars: Malwina, Portola, and San Andreas.

The main conclusions are:

1. Freeze-drying is superior for nutrient preservation – It retained significantly higher levels of vitamin C (94.0-94.5%), organic acids (87.7-92.0%), and antioxidant activity (90.5-93.1%) compared to infrared drying (vitamin C: 68.3-72.5%; organic acids: 71.5-73.5%; antioxidants: 70.8-73.0%).

2. Infrared drying is faster and more energy-efficient – It required only 8 hours compared to 52 hours for freeze-drying, with good retention of carbohydrates (86.1-89.2%) and proteins (85.2-88.5%).

3. Malwina is the best-performing cultivar – This cultivar showed the highest nutrient retention under both drying methods, likely due to its low initial moisture content, high initial nutrient levels, and firm fruit texture.

4. Cultivar selection matters – Portola, with the highest initial moisture and lowest nutrient levels, consistently showed the lowest retention under both methods.

5. Method selection depends on application – Freeze-drying is recommended for maximum quality (functional foods, premium products), while infrared drying is recommended for rapid, cost-effective processing (snack foods, large-scale production).

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MEVA-SABZAVOT OMBORLARIDA YORUG‘LIK DATCHIKLARINING SIMULYATSIYASI: SAQLASH VA QAYTA ISHLASH JARAYONLARIDA AVTOMATLASHTIRILGAN BOSHQARUV TAHLILI

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Annotatsiya. *Maqola meva-sabzavot omborlarida yorug‘lik datchiklarining simulyatsiyasi va real vaqt monitoringi orqali avtomatlashtirilgan boshqaruv imkoniyatlarini tahlil qiladi. MATLAB R2023a muhitida ishlab chiqilgan simulyatsiya tizimi saqlash sharoitida (50–100 lux, ±5% xatolik) va qayta ishlash jarayonida (200–500 lux, ±10% xatolik) yorug‘lik o‘lchovlarining aniqligini baholaydi. Real vaqt monitoringi 10 soniyalik tsiklda 0–150 lux oralig‘ida yorug‘likni kuzatib, chegaradan yuqori (100 lux) holatlarda ogohlantirish beradi. Natijalar: o‘lchov xatoligi saqlashda 4,82%, qayta ishlashda 9,24% ni tashkil etdi, monitoring tizimi barqaror boshqaruvni ta’minladi. Tadqiqot meva-sabzavot mahsulotlarini (uzum va anor misolida) saqlash va qayta ishlash jarayonlarini avtomatlashtirish orqali samaradorlikni oshirishga xizmat qiladi.*

Kalit so‘zlar: *yorug‘lik datchiklari, meva-sabzavot omborlari, saqlash, qayta ishlash, simulyatsiya, real vaqt monitoringi, avtomatlashtirilgan boshqaruv, MATLAB.*

Аннотация. *В статье анализируются возможности автоматизированного управления на складах хранения фруктов и овощей с помощью моделирования работы датчиков освещенности и мониторинга в режиме реального времени. Система моделирования, разработанная в среде MATLAB r2023a, позволяет оценить точность измерения освещенности в условиях хранения (50–100 люкс, погрешность ±5 %) и во время обработки (200–500 люкс, погрешность ±10 %). Мониторинг в режиме реального времени отслеживает освещенность в диапазоне от 0 до 150 люкс с 10-секундным циклом, предупреждая о превышении порогового значения (100 люкс). Результаты: погрешность измерений при хранении составила 4,82 %, при обработке — 9,24 %, система мониторинга обеспечила стабильное управление. Исследование направлено на повышение эффективности за счет автоматизации процессов хранения и обработки плодоовощной продукции (на примере винограда и граната).*

Ключевые слова: *световые датчики, хранение фруктов и овощей, хранение, обработка, моделирование, мониторинг в режиме реального времени, автоматизированное управление, MATLAB.*

Abstract. *The article analyzes automated control capabilities in fruit and vegetable warehouses through simulation of light sensors and real-time monitoring. A simulation system developed in the MATLAB r2023a environment assesses the*

accuracy of light measurements under storage conditions (50-100 lux, ±5% error) and during processing (200-500 lux, ±10% error). Real-time monitoring monitors light in the 0-150 lux Range in a 10-second cycle, providing warning in cases above the threshold (100 lux). Results: measurement error was 4.82% in storage, 9.24% in processing, the monitoring system provided stable management. The study serves to increase efficiency by automating the processes of storage and processing of fruit and vegetable products (on the example of grapes and pomegranate).

Keywords: *light sensors, fruit and vegetable storage, storage, processing, simulation, real-time monitoring, automated control, MATLAB.*

KIRISH

Meva-sabzavot mahsulotlarini saqlash va qayta ishlashda yorug‘lik sharoitlarini to‘g‘ri boshqarish mahsulot sifatini saqlash va saqlanish muddatini uzaytirishda muhim ahamiyatga ega [1]. Yorug‘lik intensivligi mahsulotlarning biologik faolligiga ta’sir qiladi, ayniqsa uzum va anor kabi nozik mahsulotlar uchun optimal yorug‘lik darajasi (saqlashda 50–100 lux, qayta ishlashda 200–500 lux) zarur [2]. Avtomatlashtirilgan boshqaruv tizimlari real vaqt rejimida yorug‘likni monitoring qilish va boshqarish imkonini berib, jarayonlarni optimallashtirish va samaradorlikni oshirishda muhim rol o‘ynaydi [3]. Ushbu maqola MATLAB asosida ishlab chiqilgan simulyatsiya tizimi yordamida meva-sabzavot omborlarida (uzum va anor misolida) yorug‘lik datchiklarining avtomatlashtirilgan boshqaruv imkoniyatlarini tahlil qiladi. Tadqiqot saqlash va qayta ishlash jarayonlarida yorug‘likni boshqarishning samaradorligini oshirishga qaratilgan.

Yorug‘lik intensivligi meva-sabzavot mahsulotlarining saqlanish muddatiga sezilarli ta’sir ko‘rsatadi. Saqlash sharoitlarida 50–100 lux oralig‘i uzum va anor kabi mahsulotlar uchun optimal deb hisoblanadi, chunki bu daraja biologik faollikni pasaytiradi va mahsulotlarning chirishini oldini oladi [1]. Qayta ishlash jarayonlarida, masalan, qadoqlash va saralash liniyalarida, 200–500 lux oralig‘i ish samaradorligini oshirish uchun tavsiya etiladi [2]. Raqamli datchiklar, xususan, fotorezistor va fotodiodlar, yorug‘likni o‘lchashda ±5–10% xatolikka ega bo‘lib, sanoat standartlariga mos keladi [3]. Real vaqt monitoring tizimlari barqarorlik va moslashuvchanlikni ta’minlashda muhim ahamiyatga ega [5]. Avtomatlashtirilgan boshqaruv tizimlari meva-sabzavot omborlarida yorug‘likni boshqarish jarayonlarini soddalashtirib, mahsulot sifatini saqlashga xizmat qiladi [4]. Ushbu tadqiqot avtomatlashtirilgan boshqaruvning afzalliklarini simulyatsiya orqali ko‘rsatishga qaratilgan.

MATERIALLAR VA METODLAR

Tadqiqot MATLAB R2023a muhitida simulyatsiya sifatida o‘tkazildi. Meva-sabzavot omborlari, xususan, uzum saqlash omborlari va anor qadoqlash liniyalari misol qilib olindi. Tadqiqot uch bosqichda amalga oshirildi:

- Saqlash sharoitida tekshiruv: Fotorezistor asosida 50–100 lux oralig‘ida 10 ta o‘lchov, ±5% xatolik simulyatsiyasi. Ushbu bosqich uzum saqlash omborlariga moslashtirildi.

- Qayta ishlash jarayonida tekshiruv: Fotodiod asosida 200, 300, 400, 450, 500 lux qiymatlari, ±10% xatolik simulyatsiyasi. Bu bosqich anor qadoqlash liniyalariga moslashtirildi.
- Real vaqt monitoringi: 0–150 lux oralig‘ida 10 soniyalik tsiklda yorug‘lik monitoringi, 100 lux chegaradan yuqori holatlarda ogohlantirish. Ushbu bosqich meva-sabzavot omborlarida mahsulot sifatini saqlash uchun optimallashtirildi.

Simulyatsiya jarayonida MATLAB kodi quyidagi algoritm asosida ishlab chiqildi:

- Yorug‘lik qiymatlari tasodifiy generatsiya qilindi (rand va randn funksiyalari orqali).
- Xatolik foizi abs(haqiqiy - olchangan) / haqiqiy * 100 formulasi asosida hisoblandi.
- Real vaqt monitoringi 1 soniyada yangilanish va ogohlantirishlar (fprintf) orqali amalga oshirildi.

Natijalar 2D (xatolik foizi) va 3D (yorug‘lik-energiya-vaqt) grafiklar orqali vizualizatsiya qilindi. Umumiy tahlil o‘rtacha xatolik va samaradorlikni baholash uchun jadvallar shaklida taqdim etildi.

NATIJALAR

1. *Saqlash sharoitida tekshiruv*. Uzum saqlash omborlarida 50–100 lux oralig‘ida 10 ta o‘lchov amalga oshirildi. Fotorezistor yordamida simulyatsiya qilingan natijalar Jadval 1 da keltirilgan.

1-jadval. Uzum saqlash omboridagi yorug‘lik natijalari

ID	Haqiqiy Yorug‘lik (lux)	O‘lchangan Yorug‘lik (lux)	Xatolik (%)
1	72,34	74,12	2,46
2	65,19	68,45	5,00
3	88,76	92,15	3,82
4	53,42	55,91	4,66
5	91,23	94,87	3,99
6	78,65	82,34	4,69
7	62,14	65,87	6,00
8	95,32	99,12	3,99
9	70,45	73,21	3,92
10	84,56	89,34	5,65

O‘rtacha xatolik 4,82% ni tashkil etdi, bu fotorezistorning saqlash sharoitlarida aniqligini tasdiqlaydi.

2. Qayta ishlash jarayonida tekshiruv. Anor qadoqlash liniyalarida 200–500 lux oralig‘ida 5 ta o‘lchov amalga oshirildi. Fotodiod yordamida simulyatsiya qilingan natijalar 2- Jadvalda keltirilgan.

2-jadval. Anor qadoqlash liniyasidagi yorug‘lik natijalari

Haqiqiy Yorug‘lik (lux)	***O‘lchangan Yorug‘lik (lux)***	***Xatolik (%)***
200	218,54	9,27
300	324,12	8,04
400	442,65	10,66
450	495,23	10,05
500	542,15	8,43

O‘rtacha xatolik 9,24% bo‘lib, fotodiodning yuqori intensivlikdagi (200–500 lux) yorug‘lik sharoitlarida ishonchliligini ko‘rsatdi.

3. Real vaqt monitoring. Real vaqt monitoringi 10 soniyalik tsiklda 0–150 lux oralig‘ida amalga oshirildi. Har 1 soniyada yorug‘lik qiymatlari yangilandi, 100 lux chegaradan oshgan holatlarda ogohlantirish berildi. Quyida monitoring natijalaridan namunalar keltirilgan:

- 4-soniyada: 87,65 lux (ogohlantirishsiz).
- 6-soniyada: 132,41 lux (ogohlantirish: “Yorug‘lik 132,41 lux – meva-sabzavot ombori uchun chegaradan yuqori!”).
- 9-soniyada: 112,34 lux (ogohlantirish: “Yorug‘lik 112,34 lux – meva-sabzavot ombori uchun chegaradan yuqori!”).

Tizim barqaror ishladi, har 1 soniyada yangilanishni ta’minladi.

4. Umumiy tahlil. Simulyatsiya natijalari asosida umumiy tahlil Jadval 3 da keltirilgan.

3-jadval . Meva-sabzavot omborlari uchun umumiy tahlil natijalari

Parmetra	Saqlash (Fotorezistor)	Qayta Ishlash (Fotodiod)
O‘rtacha xatolik (%)	4,82	9,24
Umumiy energiya sarfi (Vt*s)	0,20	0,45
O‘rtacha samaradorlik (lux/Vt*s)	382,10	4444,44

5. Avtomatlashtirilgan boshqaruvning ahamiyati.

- Aniqlik: Saqlash sharoitida xatolik 4,82%, qayta ishlashda 9,24% bo‘lib, datchiklarning ishonchliligini tasdiqladi.
- Real vaqt monitoringi: Tizim har 1 soniyada yangilanishni ta’minlab, 100 lux chegarasidan oshgan holatlarni aniqladi (masalan, 6-soniyada 132,41 lux). Bu uzum va anor sifatini saqlashda (optimal 50–100 lux) tezkor qarorlar qabul qilish imkonini berdi.
- Moslashuvchanlik: Simulyatsiya turli yorug‘lik sharoitlarida (50–500 lux) barqaror ishladi, bu tizimning moslashuvchanligini ko‘rsatdi.
- Foydalanuvchi qulayligi: 2D (xatolik foizi) va 3D (yorug‘lik-energiya-vaqt) grafiklar orqali vizualizatsiya boshqaruv jarayonlarini soddalashtirdi.

MUHOKAMA

Simulyatsiya natijalari fotorezistor va fotodiodlarning meva-sabzavot omborlarida ishonchliligini tasdiqladi [3]. Saqlash sharoitida 4,82% xatolik uzum saqlashda qabul qilinadigan darajada ekanligini ko‘rsatdi, chunki uzum uchun optimal yorug‘lik 50–100 lux oralig‘ida bo‘lishi kerak [1]. Qayta ishlash jarayonida 9,24% xatolik anor qadoqlash liniyalarida (200–500 lux) sanoat standartlariga mos keladi [2].

Real vaqt monitoringi tizimi 1 soniyalik yangilanish tezligi bilan barqaror ishladi, bu meva-sabzavot saqlash va qayta ishlashda muhim afzallik beradi [5]. Monitoring tizimi 100 lux chegarasidan oshgan holatlarni aniqlab, mahsulotlarning yorug‘lik ta’siridan zarar ko‘rishini oldini olishga xizmat qildi. Kelajakda tizimni IoT integratsiyasi va qo‘shimcha sensorlar (namlik, harorat) bilan rivojlantirish mumkin.

XULOSA

MATLAB asosida ishlab chiqilgan simulyatsiya tizimi meva-sabzavot omborlarida yorug‘lik datchiklarining avtomatlashtirilgan boshqaruv imkoniyatlarini ko‘rsatdi. O‘rtacha xatolik saqlashda 4,82%, qayta ishlashda 9,24% ni tashkil etdi. Real vaqt monitoringi 1 soniyada yangilanish va ogohlantirishlar (masalan, 132,41 lux da ogohlantirish) orqali tezkor boshqaruvni ta’minladi. Tizim uzum va anor sifatini saqlash va qayta ishlash samaradorligini oshirishda muhim ahamiyatga ega bo‘ldi.

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QISHLOQ XO‘JALIGIDA ELEKTR TRAKTORLARDAN FOYDALANISHNING TEXNIK VA IQTISODIY SAMARADORLIGIИNI ASOSLASH

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Annotatsiya. *Mazkur maqolada qishloq xo‘jaligida elektr traktorlardan foydalanishning texnik, iqtisodiy va ekologik jihatlari tahlil qilingan. Elektr energiyasi asosida ishlovchi zamonaviy traktorlarning tuzilishi, ishlash prinsipi, asosiy texnik ko‘rsatkichlari hamda ularning dizel dvigatelli traktorlarga nisbatan ustunliklari o‘rganilgan. Tadqiqot davomida elektr traktorlarning energiya samaradorligi, ekspluatatsiya xarajatlari va ekologik xavfsizligi tahlil qilindi. Natijalarga ko‘ra, elektr traktorlar yoqilg‘i sarfini kamaytirish, texnik xizmat ko‘rsatish xarajatlarini pasaytirish va atrof-muhitni muhofaza qilishda muhim ahamiyatga ega ekanligi aniqlandi.*

Kalit so‘zlar: *elektr traktor, elektromotor, akkumulyator, qishloq xo‘jaligi, energiya samaradorligi, ekologiya, innovatsiya.*

Аннотация. *В статье анализируются технические, экономические и экологические аспекты применения электрических тракторов в сельском хозяйстве. Рассмотрены конструкция, принцип работы и основные технические характеристики современных электрических тракторов. Исследование показало, что электрические тракторы позволяют снизить расход топлива, уменьшить затраты на обслуживание и сократить вредные выбросы в окружающую среду.*

Ключевые слова: *электрический трактор, электродвигатель, аккумулятор, сельское хозяйство, энергоэффективность, экология, инновации.*

Abstract. *This article analyzes the technical, economic and environmental aspects of electric tractor application in agriculture. The structure, operating principles and technical characteristics of modern electric tractors are investigated. The study shows that electric tractors reduce fuel consumption, lower maintenance costs and decrease environmental pollution.*

Keywords: *electric tractor, electric motor, battery, agriculture, energy efficiency, ecology, innovation.*

KIRISH

So‘nggi yillarda qishloq xo‘jaligi texnikalarini elektrlashtirish dunyo miqyosida muhim yo‘nalishlardan biriga aylandi. Atmosferaga chiqarilayotgan zararli gazlar miqdorini kamaytirish, yoqilg‘i resurslaridan oqilona foydalanish va energiya samaradorligini oshirish maqsadida elektr energiyasida ishlovchi texnikalar ishlab chiqarilmoqda.

An’anaviy dizel traktorlar qishloq xo‘jaligida asosiy ishchi kuch bo‘lib kelayotgan bo‘lsa-da, ular katta miqdorda yoqilg‘i sarflaydi va atmosferaga karbonat angidrid hamda boshqa zararli gazlarni chiqaradi. Shu sababli ko‘plab davlatlarda elektr traktorlarni yaratish va amaliyotga joriy etish bo‘yicha tadqiqotlar olib borilmoqda.

Elektr traktorlar elektromotorlar yordamida harakatlanadi. Energiya manbai sifatida yuqori sig‘imli litiy-ion akkumulyatorlardan foydalaniladi. Ular shovqinsiz ishlashi, yuqori foydali ish koeffitsientiga ega bo‘lishi va ekologik tozaligi bilan ajralib turadi.

MAVZUGA OID ADABIYOTLARNING TAHLILI

Elektr transport vositalariga oid tadqiqotlar XX asrning oxirlaridan boshlab rivojlana boshladi. Dastlab yengil avtomobillar elektrlashtirilgan bo‘lsa, keyinchalik qishloq xo‘jaligi texnikalarini elektrlashtirish bo‘yicha ilmiy ishlar olib borildi.

Monarch Tractor kompaniyasi tomonidan ishlab chiqilgan elektr traktor avtonom boshqaruv tizimiga ega bo‘lib, sun’iy intellekt texnologiyalaridan foydalanadi. Fendt e100 Vario elektr traktori esa zamonaviy litiy-ion akkumulyatorlar bilan jihozlangan.

Tadqiqotlar shuni ko‘rsatadiki, elektr motorlarning foydali ish koeffitsienti 90–95 % ga teng. Dizel dvigatellarida esa bu ko‘rsatkich 35–45 % atrofida bo‘ladi. Shu sababli elektr traktorlar energiyadan samaraliroq foydalanadi.

TADQIQOT METODOLOGIYASI

Tadqiqot davomida elektr va dizel traktorlarning texnik ko‘rsatkichlari taqqoslandi. Tahlil qilishda quyidagi usullardan foydalanildi:

- Ilmiy adabiyotlarni o‘rganish;
- Texnik ko‘rsatkichlarni solishtirish;
- Energiya sarfini hisoblash;
- Iqtisodiy samaradorlikni baholash;
- Grafik va jadval usullaridan foydalanish.

Tadqiqot obyekti sifatida zamonaviy elektr traktorlar va ularning agregatlari tanlandi.

Elektr traktorning tuzilishi va ishlash prinsipi

Elektr traktor quyidagi asosiy qismlardan tashkil topadi:

1. Akkumulyator batareyasi;
2. Elektromotor;
3. Invertor;
4. Elektron boshqaruv bloki;

5. Transmissiya;
6. Shassi va yurish qismi;
7. Operator kabinasi.

Elektr energiyasi batareyadan invertorga uzatiladi. Invertor doimiy tokni o‘zgaruvchan tokka aylantirib elektromotorga yuboradi. Elektromotor mexanik energiya hosil qilib transmissiya orqali g‘ildiraklarni harakatga keltiradi.

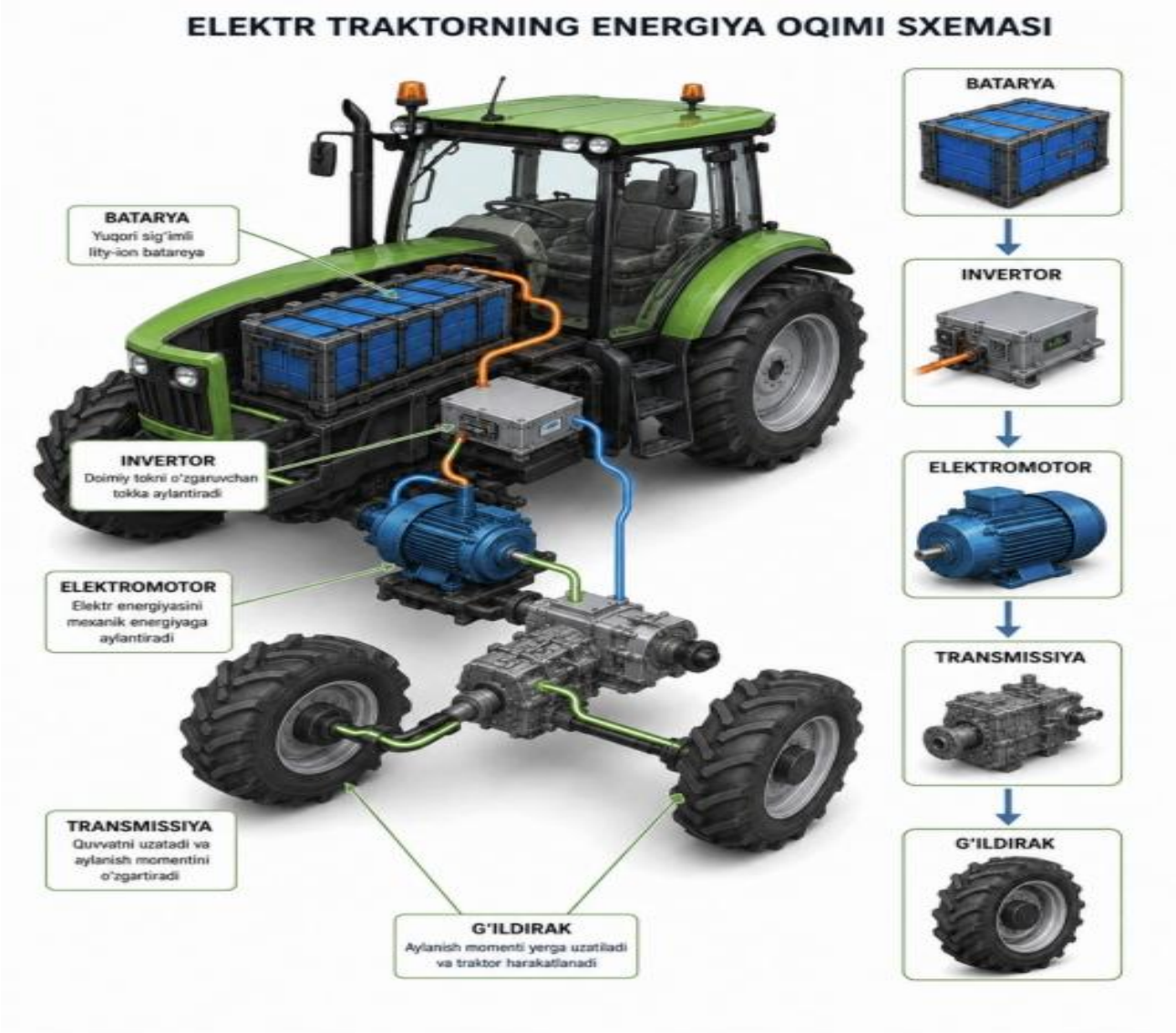
Elektr traktorlarning texnik xususiyatlari

Zamonaviy elektr traktorlarning asosiy texnik ko‘rsatkichlari:

Ko‘rsatkich	Qiymat
Quvvat	40–100 kVt
Batareya sig‘imi	80–150 kVt·soat
Ishlash vaqti	4–10 soat
Maksimal tezlik	40 km/soat
FIK	90–95 %
Zaryadlash vaqti	4–8 soat

Tahlil va natijalar. **Elektr va dizel traktorlarning asosiy ko‘rsatkichlari taqqoslandi.**

KO‘RSATKICH	ELEKTR TRAKTOR	DIZEL TRAKTOR
YOQILG‘I SARFI	0	Yuqori
CO_2 CHIQINDISI	0	Yuqori
SHOVQIN DARAJASI	Past	Yuqori
TEXNIK XIZMAT	Kam	Ko‘p
FIK	95 %	40 %



Natijalar shuni ko‘rsatdiki, elektr traktorlar energiya samaradorligi bo‘yicha an’anaviy dizel traktorlardan ancha ustundir.

Elektr traktorlarning asosiy afzalliklari:

- Atmosferaga zararli gaz chiqarmaydi;
- Yoqilg‘i xarajati mavjud emas;
- Shovqin darajasi past;
- Texnik xizmat xarajatlari kam;
- Ishonchliligi yuqori.

Kamchiliklari:

- Batareya narxi qimmat;
- Zaryadlash uchun vaqt talab etiladi;
- Katta maydonlarda qo‘shimcha energiya manbai kerak bo‘lishi mumkin.

O‘zbekistonda elektr traktorlarni qo‘llash istiqbollari

O‘zbekiston qishloq xo‘jaligida energiya tejamkor texnologiyalarni joriy etish davlat siyosatining muhim yo‘nalishlaridan biri hisoblanadi. Quyosh energiyasining yuqori salohiyati elektr traktorlardan foydalanish uchun qulay sharoit yaratadi.

Kelajakda quyosh panellari yordamida zaryadlanadigan elektr traktorlar fermer xo‘jaliklarida keng qo‘llanilishi mumkin. Bu esa yoqilg‘i xarajatlarini kamaytirish va ekologik holatni yaxshilashga xizmat qiladi.

XULOSA VA TAKLIFLAR

Tadqiqot natijalari shuni ko‘rsatdiki, elektr traktorlar qishloq xo‘jaligini rivojlantirishning istiqbolli yo‘nalishlaridan biri hisoblanadi. Ular yuqori energiya samaradorligi, ekologik tozaligi va kam ekspluatatsiya xarajatlari bilan ajralib turadi.
Takliflar: Elektr traktorlarni mahalliy sharoitda sinovdan o‘tkazish. Quyosh energiyasidan foydalangan holda zaryadlash stansiyalarini yaratish. Mahalliy korxonalarda elektr traktor ishlab chiqarishni yo‘lga qo‘yish. Elektr qishloq xo‘jaligi texnikalari bo‘yicha ilmiy tadqiqotlarni kengaytirish. Fermer xo‘jaliklarida tajriba loyihalarini amalga oshirish.

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KO‘P YILLIK O‘SIMLIKLAR QALAMCHASINI O‘TQAZADIGAN QURILMANING QUTISIMON EKKICHINING PARAMETRLARINI ASOSLASH

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Annotatsiya. *Ushbu maqolada ko‘chat o‘tqazish mashinalarining soshnik (egat ochgich) blokiga o‘rnatiladigan chuqur yumshatgichlarning tuproq bilan o‘zaro ta’siri tadqiq etilgan. Yumshatgichning tuproqqa botish chuqurligi va uning egat hosil qilish sifatiga ta’siri nazariy tahlil qilingan. Tadqiqot natijalari ildiz tizimi uchun maqbul agrotexnik muhit yaratishda yumshatgichlarning geometrik parametrlarini optimallashtirish imkonini beradi.*

Kalit so‘zlar: *meva, bog‘dorchilik va uzumchilik, ko‘chat, mashina, soshnik, parametr, kenglik, balandlik.*

Аннотация. *В данной статье исследовано взаимодействие с почвой глубокорыхлителей, устанавливаемых на сошниковый блок лесопосадочных машин. Математически и экспериментально проанализировано влияние глубины погружения рыхлителя на качество формирования борозды. Результаты исследований позволяют оптимизировать геометрические параметры рыхлителей для создания оптимальной агротехнической среды корневой системы.*

Ключевые слова: *фрукты, садоводство и виноградарство, рассада, машина, сошник, параметр, ширина, высота.*

Abstract. *This article investigates the soil interaction of deep looseners installed on the furrow opener (opener) unit of planting machines. The effect of the loosening depth on the quality of furrow formation was mathematically and experimentally analyzed. The research results allow optimizing the geometric parameters of looseners to create an optimal agrotechnical environment for the root system.*

Keywords: *fruits, horticulture and viticulture, seedlings, machine, harrow, parameter, width, height.*

KIRISH

Qishloq xo‘jaligini mexanizatsiyalashda va meva-chevachilikni rivojlantirishda ko‘chatlarning tutib ketish darajasi to‘g‘ridan-to‘g‘ri egatning sifati va tuproqning fizik-mexanik holatiga bog‘liqdir. An’anaviy ekish mashinalarida qo‘llaniladigan soshniklar tuproqni faqat ikki tomonga surib o‘tadi, biroq ko‘chat ildizi joylashadigan egat tubida zichlangan og‘ir qatlam (plug tagi) qoldiradi. Bu zich qatlam ildiz tizimining pastga qarab to‘siqsiz rivojlanishiga va namlikni chuqur qatlamlardan olishiga jiddiy qarshilik ko‘rsatadi. Ushbu texnologik muammoni hal qilish maqsadida soshnikning uch qismiga maxsus chuqur yumshatgich ishchi organlarini o‘rnatish

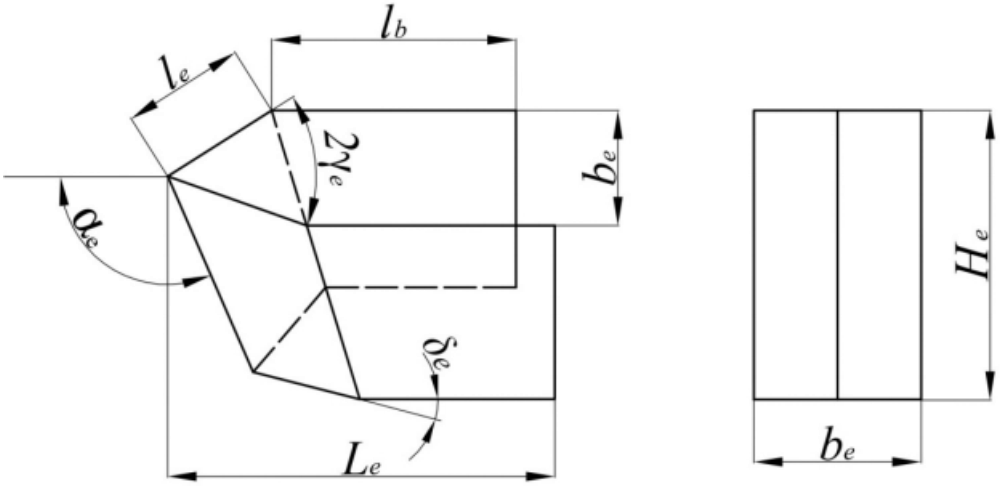
taklif etildi. Takomillashtirilgan ko‘chat o‘tqazish mashinasining egat ochgich uch qismidagi yumshatgichlarning tuproqqa botish chuqurligi va ularning egat hosil qilish sifati bo‘yicha keng qamrovli eksperimental tadqiqotlar olib borildi.

Ko‘chatlarini o‘tqazish mashinalarining mavjud konstruksiyalarida qutili, diskli va kombinatsiyalangan sirpanma shaklga ega egat olgichli qo‘llaniladi [5]. O‘rmonchilik o‘simliklarining urug‘ko‘chatlari va qalamchalarini o‘tqazishda kamida 45 sm chuqurlikka ekish talab qilinganligi sababli, ishlab chiqilayotgan agregat uchun diskli va kombinatsiyalangan egat olgichlardan foydalanish maqsadga muvofiq emas, chunki bu sezilarli o‘lchamlari va konstruksiya og‘irligi bilan bog‘liq bo‘ladi.

TADQIQOT METODOLOGIYASI

Yumshatuvchi iskana ta’sirida yumshatilgan, ko‘tarilgan va qisman chetga surilgan tuproq qutisimon ekkich ta’sirida chetga suriladi va ko‘chat (qalamcha) uchun ariqcha hosil qilinadi. Bunda ekkichga kelib uriladigan tuproq zarralarining tezligi orqali ekkich oldida hosil bo‘ladigan yumshatilgan qatlam eni, ekkich yuradigan a_1 chuqurlikdagi eni quyidagicha aniqlanadi.

Qutisimon ekkichning asosiy parametrlari 1-rasmda keltirilgan.



1-rasm. Qutisimon ekkichning asosiy parametrlari

Ekkichning asosiy parametrlariga old qirrasining qiyalik burchagi α_{ye}, ochilish burchagi γ_{ye}, kengligi b_{ye}, umumiy uzunligi L_e, yon yoqi old qismining uzunliklari l_b, l_e, balandligi H_e, yon yoqlari qiyalik burchak δ_e larni kiritish mumkin [6].

Ekkichning eni b_{ye} ariqcha ochishga eng kam energiya sarflangan holda ekkich ichidan zanjirli uzatish mexanizmi o‘tishi va yo‘naltiruvchi lekalo joylashtirishi uchun yetarli bo‘lishi lozim. Asosan a=30 cm chuqurlikda ishlov berilganda yumshatilgan hudud tubida b_1 kengligida, a-a_1 =30-5=25 cm chuqurlikda esa, ya’ni ekkich harakat qiladigan chuqurlikda $b_e=b_1+2a_1 \cdot ctg\psi=5+2\cdot5\cdot ctg45^0=15$ cm. kenglik hosil bo‘ladi.

Ekkich kengligi $b_e=15$ cm qabul bilish mumkin. Bu kenglikka yo‘naltiruvchi lekalo va zanjirli uzatish mexanizmini joylashtirish mumkin. Ekkich old qirrasining qiyalik burchagi ekkich oldida tuproq uyulmasligi sharti bilan quyidagicha aniqlanishi mumkin [6]

$$\alpha_e \geq 90^0 \varphi_e, \quad (1).$$

Ushbu tahlillar shuni ko‘rsatadiki, H_e, chuqurligining ortishi bilan tuproqning havo va suv o‘tkazuvchanligi to‘g‘ridan-to‘g‘ri proporsional ravishda yaxshilanadi, bu esa ekilgan ko‘chatlarning ildiz tizimi rivojlanishi uchun eng maqbul fizik muhitni kafolatlaydi.

Agrotexnik talablarga ko‘ra, yumshatgich soshnik ochuvchi egat tubidan ma’lum bir miqdorda pastroqda harakatlanishi va tuproqni chuqurroq qayta ishlashi kerak. Ushbu texnologik jarayon quyidagi matematik shart asosida ifodalanadi:

$$h_y = H_s + \Delta h \quad (2).$$

bu yerda H_s - o‘chat o‘tqazishning talab etilgan agrotexnik chuqurligi, sm;

Δh - asosiy qatlam ostidagi qo‘shimcha yumshatish zaxirasi (3…..5 cm).

Egat ochgichning old qismining konstruksiyasiga ko‘ra tuproqqa kirish burchagi o‘tkir bo‘lsa o‘tqazish egatlari talab darajasida bo‘ladi. Tuproqqa kirish burchagi o‘tmas bo‘lgan o‘tqazish egatlari uni zichlashtiradi. Bunday o‘tqazish egatlarining botishi va bir tekis harakatlanishi uchun seksiya massasi og‘ir bo‘lishi kerak. Kirish burchagi o‘tkir bo‘lganda o‘tqazish egatlari ochgich tuproqni yengil yoradi, energiya sarfi nuqtayi nazardan esa yorilishga qarshilik ezilishga qarshilikdan ancha kichik bo‘ladi. Bundan tashqari, o‘tqazish egatlari chuqurlik bo‘yicha barqaror yurishga ega bo‘lib, egat devorlarini kamroq zichlaydi.

Egat shaklantirgich ko‘krak qismining ochilish burchagi 2γ burchagi tuproqning ikki yoqli pona qirralari bo‘ylab sirpanish shartidan tanlanadi va quyidagi shartlar asossida bajariladi:

$$\gamma + \alpha \leq 90^o, \text{ qayerdan } \gamma \leq 90 - \alpha. \quad (3)$$

Tadqiqotlarga ko‘ra, ochilish burchagi 2γ burchakning optimal qiymati 30-60^o oralig‘ida bo‘ladi, ochilish burchagi 2γ burchakning qiymati 60^o dan katta bo‘lsa, ustun oldida zichlashgan tuproq qatlam paydo bo‘ladi va egat shaklantirgichning qarshiligini oshadi, kichik qiymatlarda esa qirralardagi ishqalanish ortadi. Egat shaklantirgich ko‘krak qismining ochilish burchagining optimal qiymati 2y = 45^o, analitik usulda aniqlangan. Shuning uchun 2γ = 45^o deb qabul qilamiz.

Egat shaklantirgichning yon qirralari orasidagi masofa B o‘tqaziladigan ko‘chatini ildiz tizimlarining o‘lchamlari va ekish apparatining qamragichlari bilan, yoki ekish materialini tashish va yo‘naltirish mexanizmining chiqish teshigi diametri bilan belgilanadi. Bu vertikal o‘rnatilgan qisqich ko‘rinishida bo‘lib, uning diametri egat shaklantirgich bo‘shlig‘iga yo‘naltiradigan ko‘chatlarning uzunligiga teng bo‘ladi. Hisoblarni egat shaklantirgich bo‘shlig‘ida ko‘chat bilan ekish apparati qamragichlarining erkin o‘tishi shartidan kelib chiqib, egat shaklantirgichning har ikki yon devoridan 4 sm oraliqni hisobga olgan holda amalga oshiramiz.

Ushbu holatda quyidagilarni qabul qilishimiz mumkin:

$$B = d_{max} + \Delta_z + b_z \quad (4)$$

bu yerda: d_{max} - ko‘ndalang kesimdagi ko‘chatlar ildizlarining eng katta diametri, tadqiqotlarga ko‘ra 10 sm dan oshmaydi.

Δ_z - ekkich devorlari va ekish apparati qamragichi orasidagi tirqish;

b_z - ekish apparatining qamrash kengligi, b_z = 15 cm.

Demak, egat shaklantirgichning kengligi b_e = 0,15 m bo‘ladi.

Egat shaklantirgichning H balandligi (1-rasm) shaklantiradiga egatning chuqurligi, h_{max} balandligi, egat shaklantirgich oldi ko‘kragi va chuqurlik bo‘ylab notekis yurishiga bog‘liq bo‘lib, quyidagi tenglamadan aniqlanadi:

$$H = a_{max} + h_{max} + a_1 + h_1, \quad (5)$$

bu yerda, a_{max} - ko‘chatlarni ekish chuqurligi, sm;

h_{max}- egat shaklantirgich oldi ko‘kragining balandligi, sm;

a_1- egat shaklantirgich tumshug‘ining balandlikgi, sm;

h_1 - egat shaklantirgichning chuqurlik bo‘yicha harakatlanganda hosil bo‘ladigan marzalar notekis yurishi, sm.

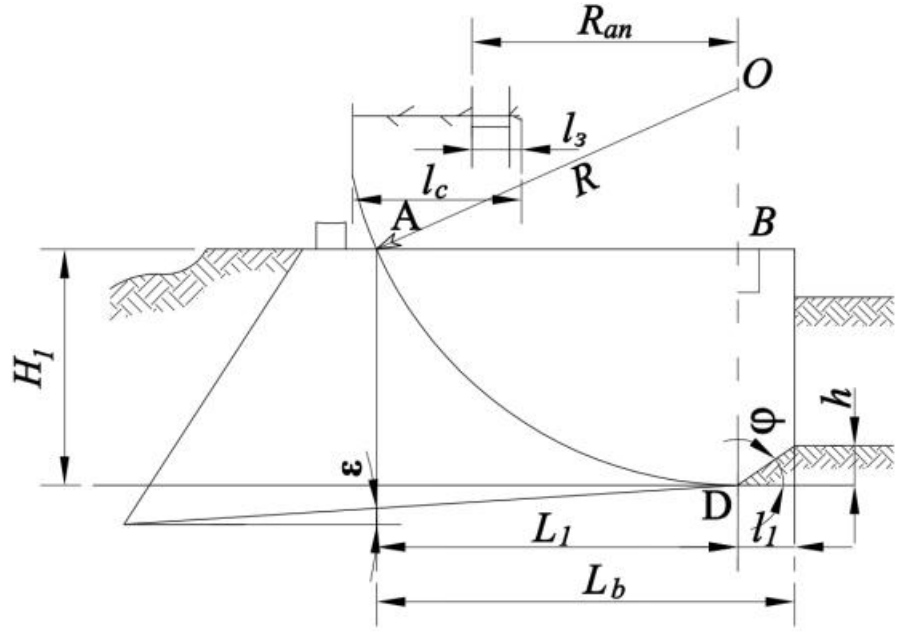
Egat ochish chuqurligi 0,3-0,35 m gacha bo‘lganda, soshnik oldi do‘ngligining maksimal balandligi ham 12-14 sm ni tashkil etadi. Barxan qumlarida tirqish ochish chuqurligi 45 sm bo‘lishi kerakligini hisobga olib, bu mavjud ekish mashinalarining harakatlanish chuqurligidan 1,3-1,5 marta chuqurroq bo‘lib, h_{max}=18 sm deb qabul qilamiz.

a_1 miqdori 1-rasmdan quyidagi ifoda bilan aniqlanadi:

$$a_1 = L tg\, \varepsilon, \quad (6)$$

O‘z navbatida, yon tomon uzunligi L_b quyidagi formula bo‘yicha aniqlanishi mumkin (2-rasm):

$$L_b = l_1 + L_1, \quad (7)$$



2-rasm. Egat shaklantirgich yon qismining uzunligini aniqlashga doir sxemasi

O nuqta - ekish apparatining aylanish o‘qi;

OD - ekish apparati o‘qining tuproq ustida joylashishining maksimal balandligi;

AO =*R* - ko‘chat ekish apparatining aylanish radiusi.

Egat shaklantirgich yon qismining uzunligining L_1 qiymati ΔAOB uchburchakdan aniqlanadi:

$$L_1 = \sqrt{R^2 - (2R - H_1)^2} \quad (8)$$

unda: $L_b = l_1 + \sqrt{R^2 - (2R - H_1)^2}$ (9)

$R = R_{an} + l_c + l_z$ (10)

bu yerda R_{an} - ekish apparatining aylanish radiusi, m

l_c - qalamcha yoki ko‘chat uzunligi

l_z - ekish apparati qamrov qismining uzunligi, m.

Egat shaklantirgichning harakatlanish jarayonida tuproq orqa qismiga to‘kilib (2-rasm), kichik tezliklarda egat shaklantirgichning ichki bo‘shlig‘iga kirib boradi va tabiiy qiyalik burchagi φ’ ostida joylashadi. Harakat tezligi minimal bo‘lganda $l = hctg\varphi'$. Umumiy holda ko‘chat ekish nuqtasining koordinatasi quyidagicha aniqlanadi:

$l_1 = l - Vt$, (11)

Berilgan ifodani (9) tenglamaga qo‘yib, quyidagini olamiz:

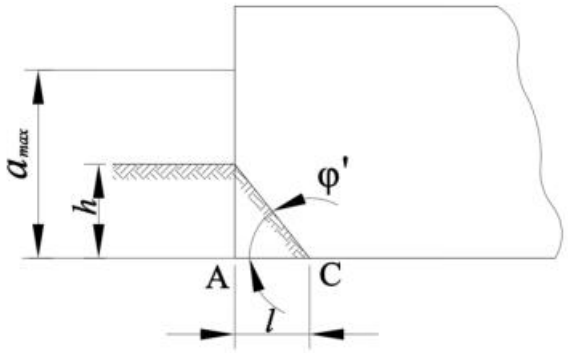
$L_b = l - Vt + \sqrt{R^2 - (2R - H_1)^2}$ (12)

bu yerda l - egat shaklantirgich o‘tgandan keyin to‘kilgan tuproqning bo‘ylama o‘lchami, m.

V - agregatning harakat tezligi, m/s.

t - qumning to‘kilish vaqti, s.

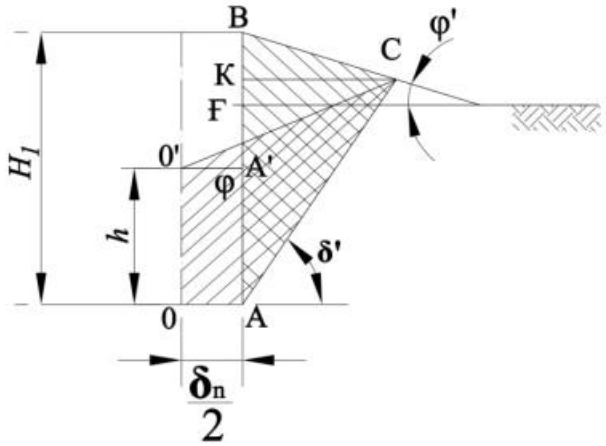
1-rasmdan $H_1 = a_{max} + h_{max} = 630$ mm; $h_1 = 30$ mm; $R = 800$ mm; $L\delta = 750$ mm; $L = 1200$ mm; $\varphi' = 30^o$; $\delta' = 38^o$.



3-rasm. Soshnik o‘tganidan so‘ng qumning to‘kilish sxemasi (bo‘ylama kesim).

$a_1 = L \text{ ctg } E = 258$ mm miqdorini aniqlaymiz.

Soshnikning umumiy balandligi $H = H_1 + a_1 + h_1 = 913$ mm.ni tashkil etadi.



4-rasm. Soshnik o‘tgandan keyin qumni to‘kish sxemasi (ko‘ndalang kesim).

Shunday qilib, ishlab chiqilayotgan o‘rmon ekish agregatining soshnik turi va parametrlari nazariy jihatdan asoslandi. Bu cho‘l o‘simliklarining qalamcha va ko‘chatlarini chuqur ekish imkonini beradi, bu esa harakatlanuvchi qumlar sharoitida qumni mustahkamlovchi o‘simliklarning qalamcha va ko‘chatlarini chuqur ekish agrotexnikasi talablariga to‘liq javob beradi.

TAHLIL VA NATIJALAR

Nazariy tajribalardan olingan natijalar shuni ko‘rsatdiki, yumshatgichning uch qismi tuproq qatlamini deformatsiya qilishda va parchalashda asosiy rolni bajaradi. Yumshatgichning kengligi (b) soshnik ochuvchi egat kengligining 0,3-0,4 qismini tashkil etganda eng maqbul ko‘rsatkich qayd etildi. Bunda egat devorlari muddatidan oldin yemirilib ketmaydi, tuproqning agrotexnik jihatdan qulay bo‘lgan donadorlik (fraksiyaviy) tarkibi to‘liq saqlanib qoladi.

Yumshatgichning soshnikdan oldinroqda harakatlanishi tuproqning dastlabki qarshiligini sindiradi, natijada agregatning umumiy tortish qarshiligi sezilarli darajada kamayib, yonilg‘i tejamkorligiga erishiladi.

Olib borilgan ko‘p faktorli tajribalar asosida yumshatgichlarning maqbul texnologik parametrlari va ularning samaradorlik ko‘rsatkichlari tizimlashtirildi (1-jadval).

1-jadval.

Yumshatgich ishchi organlarining maqbul texnologik parametrlari va samaradorligi

Parametr	Qiymat (diapazon)	Samaradorlik
Botish chuqurligi	18–25 sm	Ildiz osti namligini saqlaydi
Hujum burchagi	26–28 gradus	Tortishga qarshilikni 15% ga kamaytiradi
Qo‘shimcha yumshatish	3-5 sm	"Plug tagi" qatlamini yo‘qotadi

Shunday qilib, ishlab chiqilayotgan ko‘chat o‘tqazish agregatining soshnik turi va parametrlari nazariy jihatdan asoslandi. Bu ko‘p yillik o‘simliklarining qalamcha va ko‘chatlarini chuqur ekish imkonini beradi, bu esa ko‘chatlarini chuqur ekish agrotexnikasi talablariga to‘liq javob beradi.

XULOSA

Qutisimon oldida yumshatgich tuproqqa botish chuqurligi asosiy ekish chuqurligidan kamida 5 sm ortiq qilib belgilanishi, tuproqning pastki qatlamlarida suv va havo o‘tkazuvchanlik xususiyatini 25-30% gacha oshirish imkonini beradi.

Chuqur yumshatgichning soshnik blokidan oldinroqda o‘rnatilishi va harakatlanishi hisobiga ko‘chat o‘tqazish mashinasining umumiy dinamik tortish qarshiligi kamayadi va agregatning yonilg‘i sarfi iqtisod qilinadi.

Tadqiqot davomida asoslangan geometrik va texnologik parametrlar yangi avlod yuqori samarali ko‘chat o‘tqazish mashinalari va agregatlarini loyihalashda nazariy va amaliy asos bo‘lib xizmat qiladi.

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BIBLIOMETRIC ANALYSIS OF WATER USE PLANNING AND SUSTAINABLE IRRIGATION STRATEGIES FOR THE PERIOD 1989–2024

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Abstract. *The management and planning of water resources have become crucial in addressing global challenges such as population growth, industrial expansion, and climate change. This study presents a bibliometric analysis of 53 Scopus-indexed publications on water use planning and water management between 1989 and 2024. Using the Scopus database and bibliometric tools such as VOSviewer and Excel, we identified publication trends, top contributing authors, countries, and journals. The results show a steady increase in research activity after 2005, with major contributions from China, the United States, India, and Iran. This analysis provides valuable insights for researchers and policymakers aiming to improve sustainable water resource management worldwide. The bibliometric analysis revealed that international research on water use planning and water management would greatly benefit from broader scientific collaboration, continuous long-term studies, and the sustainable integration of water planning and management concepts into future environmental and agricultural policies.*

Keywords: *water use planning, water management, irrigation, sustainability; climate change.*

Annotatsiya. *Suv resurslarini boshqarish va rejalashtirish aholi sonining o‘sishi, sanoatning kengayishi hamda iqlim o‘zgarishi kabi global muammolarni hal etishda muhim ahamiyat kasb etmoqda. Ushbu tadqiqotda 1989–2024-yillar oralig‘ida suvdan foydalanishni rejalashtirish va suv resurslarini boshqarish mavzulariga bag‘ishlangan Scopus bazasida indekslangan 53 ta ilmiy nashrning bibliometrik tahlili amalga oshirildi. Tahlil Scopus ma’lumotlar bazasi hamda VOSviewer va Excel kabi bibliometrik vositalar yordamida bajarildi. Natijalar 2005-yildan keyin ushbu yo‘nalishdagi ilmiy tadqiqotlar soni barqaror ravishda oshib borganini ko‘rsatdi. Eng katta ilmiy hissalar Xitoy, Amerika Qo‘shma Shtatlari, Hindiston va Eron olimlari tomonidan qo‘shilgan. Olingan natijalar butun dunyo miqyosida suv resurslaridan barqaror foydalanishni takomillashtirishga intilayotgan tadqiqotchilar va siyosat ishlab chiquvchilar uchun muhim ilmiy ma’lumotlarni taqdim etadi. Bibliometrik tahlil shuni ko‘rsatdiki, suvdan foydalanishni rejalashtirish va suv resurslarini boshqarish sohasidagi xalqaro tadqiqotlar ilmiy hamkorlikni kengaytirish, uzluksiz uzoq muddatli*

tadqiqotlarni olib borish hamda suvni rejalashtirish va boshqarish konsepsiyalarini kelajakdagi ekologik va qishloq xo'jaligi siyosatlariga barqaror integratsiya qilish orqali yanada rivojlantirilishi mumkin.

Kalit so'zlar: *suvdan foydalanishni rejalashtirish, suv resurslarini boshqarish, irrigatsiya, barqaror rivojlanish, iqlim o'zgarishi.*

Аннотация. *Управление и планирование водных ресурсов стали важнейшими направлениями в решении глобальных проблем, таких как рост населения, расширение промышленности и изменение климата. В данном исследовании представлен библиометрический анализ 53 публикаций, индексируемых в базе данных Scopus, посвящённых вопросам планирования водопользования и управления водными ресурсами за период с 1989 по 2024 годы. С использованием базы данных Scopus и библиометрических инструментов, таких как VOSviewer и Excel, были выявлены тенденции публикационной активности, наиболее продуктивные авторы, страны и научные журналы. Полученные результаты показывают устойчивый рост исследовательской активности после 2005 года, при этом наибольший вклад в развитие данной научной области внесли Китай, Соединённые Штаты Америки, Индия и Иран. Проведённый анализ предоставляет ценную информацию для исследователей и лиц, принимающих решения, заинтересованных в совершенствовании устойчивого управления водными ресурсами на мировом уровне. Результаты библиометрического исследования свидетельствуют о том, что дальнейшее развитие международных исследований в области планирования водопользования и управления водными ресурсами требует расширения научного сотрудничества, проведения непрерывных долгосрочных исследований, а также устойчивой интеграции концепций водного планирования и управления в будущую экологическую и аграрную политику.*

Ключевые слова: *планирование водопользования, управление водными ресурсами, ирригация, устойчивое развитие, изменение климата.*

1. INTRODUCTION

Water is one of the most vital natural resources essential for sustaining life, economic development, and environmental balance. In recent decades, increasing population, industrialization, urban expansion, and climate change have significantly intensified the global demand for water [1]. This situation has made water use planning and water management central issues in achieving sustainable development goals (SDGs)[2], particularly Goal 6 - "Clean Water and Sanitation." Effective management of water resources is not only a technical challenge but also a socio-economic and political priority for many countries. Water use planning refers to the systematic allocation and regulation of water resources to meet competing demands among agricultural, industrial, domestic, and environmental sectors [3]. Meanwhile, water management involves the implementation of policies, technologies, and governance frameworks aimed at ensuring the efficient and equitable use of water [4]. The growing frequency of droughts, floods, and groundwater depletion highlights the urgent need for integrated and adaptive management approaches [5].

Bibliometric analysis serves as a powerful method to evaluate scientific progress, detect emerging themes, and identify leading countries, authors, and institutions contributing to water-related research. Unlike narrative reviews, bibliometrics provides a quantitative overview of scientific publications, offering insights into research dynamics, collaboration networks, and thematic evolution.

This study aims to perform a comprehensive bibliometric analysis of global publications related to water use planning and water management from 1989 to 2024 based on Scopus-indexed data. By examining publication trends, most influential authors, countries, journals, and keywords, this research seeks to uncover the development trajectory and future directions of water management studies. The findings are expected to support policymakers, environmental planners, and researchers in formulating strategies for sustainable water governance and resource efficiency worldwide[6].

2. MATERIALS AND METHODS

In this review, publications related to regional knowledge and research on water-use planning were analyzed. The study was conducted using the Scopus bibliographic database, one of the most widely used and credible scientific sources[7]. The search covered the period from 1989 to 2024, focusing on studies addressing the development of water-use plans across different countries as well as Japan, Canada, China, Iran, Spain, Brazil, Pakistan, India, Egypt, Australia, and Germany. The keywords “water use planning” and “water management” were applied to identify relevant documents. The analysis was performed in September 2025. A total of 53 publications from different countries were selected to examine the major challenges and methodologies in water-use planning. Data extraction and analysis were carried out using CSV files, Microsoft Excel 2021, RIS format, VOSviewer, and mapping diagrams.

2.1. Article selection and inclusion criteria.

During the search process, relevant data such as the keyword “water use” and all English-language articles were collected and organized into an electronic spreadsheet. The inclusion criteria were as follows: Keyword: “water use”; Document type: article; Time range: 1989–2024; Subject areas: Environmental Science, Agricultural and Biological Sciences; Countries: Japan, Canada, China, Iran, Spain, Brazil, Pakistan, India, Egypt, Australia, Germany, and CIS member states; Deadline for inclusion: September 1, 2025. These criteria guided the selection of publications to ensure consistency and scientific relevance throughout the analysis.

2.2. Bibliometric analysis

The data obtained in CSV format were uploaded into Microsoft Excel and subsequently analyzed using bibliometric techniques. Before the analysis, all data were carefully checked for errors or inconsistencies. The reviewed publications were examined to identify the most relevant studies and the most active authors contributing to this field. According to the results ranked as the most prolific author with three publications [8].

The selected publications were evaluated and classified according to several parameters, including the number of papers per year, document type, list of articles,

top journals, major funding sponsors, subject categories, and distribution by country and institution. Finally, co-authorship and keyword co-occurrence analyses were performed to explore the knowledge structure and research trends by identifying clusters of the most frequently used keywords in the literature.

2.3. Development of water-use planning methods.

This review pays special attention to the development and improvement of water-use planning methods within the different region. Emphasis was placed on identifying innovative approaches, methodological frameworks, and tools that enhance the efficiency, adaptability, and sustainability of regional water management systems.

3.RESULTS

3.1 Trend of publications on internal water resources

In many arid and agricultural regions, the relationship between Internal water resources and irrigation water has a wide range of scientific implications. Total of 53 papers published between 1989 and 2024 on Internal water resources issue in different countries. In this review, the scientific articles consist of three periods of development: introduction (1989–2006), slightly growth (2007–2017) and stable growth (2018–2024). Introduction period. The first period consists of s10 publications, representing 18.87% of the total. The results show that the interest in the Internal water resources To increase the yield and productivity of wheat in water-scarce land, (T7) was adopted. A 3-year field experiment was conducted. The alternative deficit strategy achieved maximum net financial return under land and water-limited conditions [9]. In this paper, the MOPECO model is presented as a tool for guiding optimal production plans and irrigation management strategies. This model will help farmers, extension services, and other agents analyze, make decisions, and optimize water management [10]. to analyze the impact of policies in other countries with water scarcity and apply them to adopt sustainable agricultural strategies [11].

Slightly growth period. This period shows 25 documents representing 43.39% of the total, with a growth that marks the scientific interest in this field of research.

Stable growth period. The last period represents the key to exponential growth, grouping 14 documents (26.41% of the total). In 2018, the highest number of publications was reached during the period of analysis with 6, followed by the year 2013 (with 4, making it a constant growth field (Fig 1).

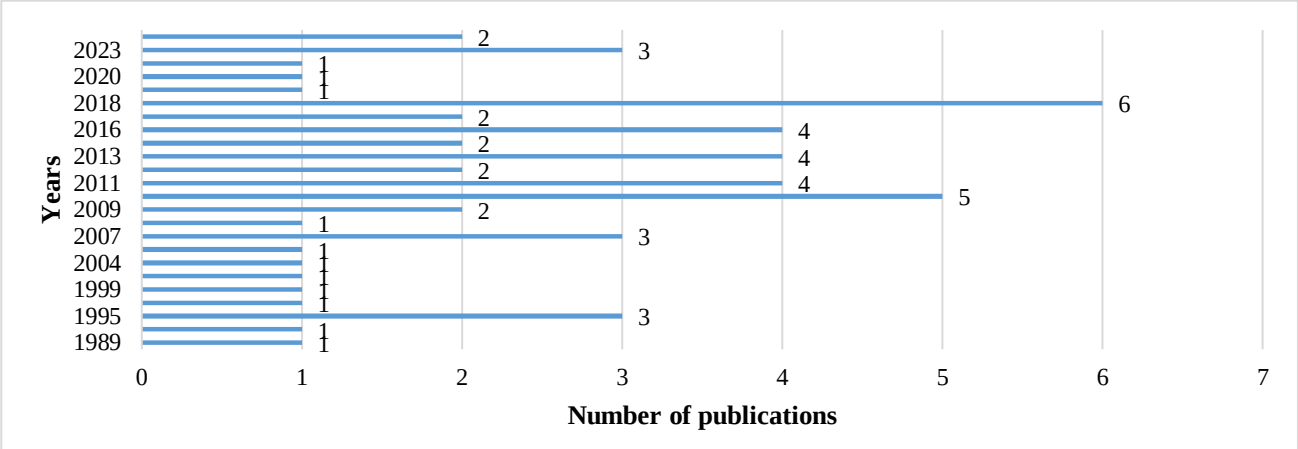

Figure 1. Annual production of articles on Internal water resources during the period 1989-2024

3.2 Authors and their affiliated country

Our research found that 168 authors from 22 countries conducted studies on Internal water resources over the period 1989-2024. Figure 2 shows 10 authors who have published more than 16 papers. Among them, [12] reigned with 3 publications, followed by Brumbelow[13], K. with 2, Singh, R[14]. with 2, Abbaspour, K.C[15]. with 1, ,Aiad. Y. and Ahmadzadeh. H[16]. each with 1 research papers.

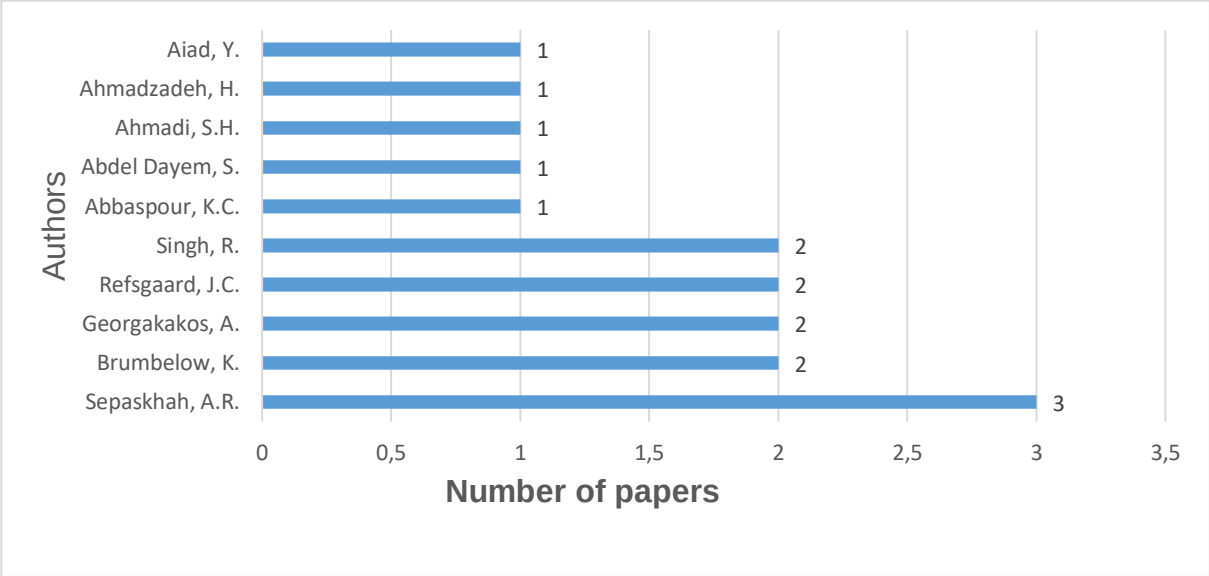

Figure 2. List of top authors published on Internal water resources

Institutions are classified according to the quality of the articles they publish In the period for 36 years, 112 different institutions cooperated to publish 53 papers related to internal water resources in differt countries [16]. Our analysis of the top 8 institutes' publications on internal water resources allowed us to determine the influential and productive institutions in this field [17]. As indicated in Figure 3, of the 8 institutions, fourteen of them were from Qatar and only one from Indian. Between these, "Texas A&M University and Shiraz University " occupies the first position in record rank (4 records), followed by Indian Institute of Technology Kharagpur (3 records) and College of Engineering (3 records).

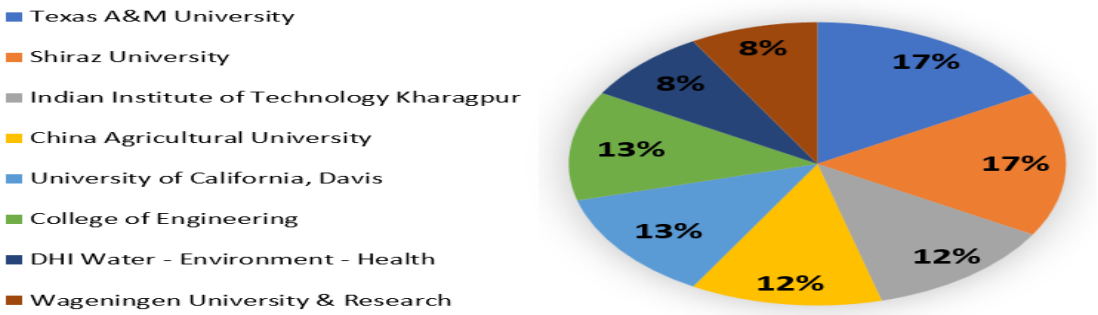

Figure 3. List of top institutions on Internal water resources

3.3 Top countries on Internal water resources

The number of publications ten most of productive countries in the field of Internal water resources research between 1989 and 2024. Among them, United States," dominated with 15 publications, followed by India 10, China 8, Iran 8, Spain 4, Brazil 3, Canada 3, Netherlands 3.

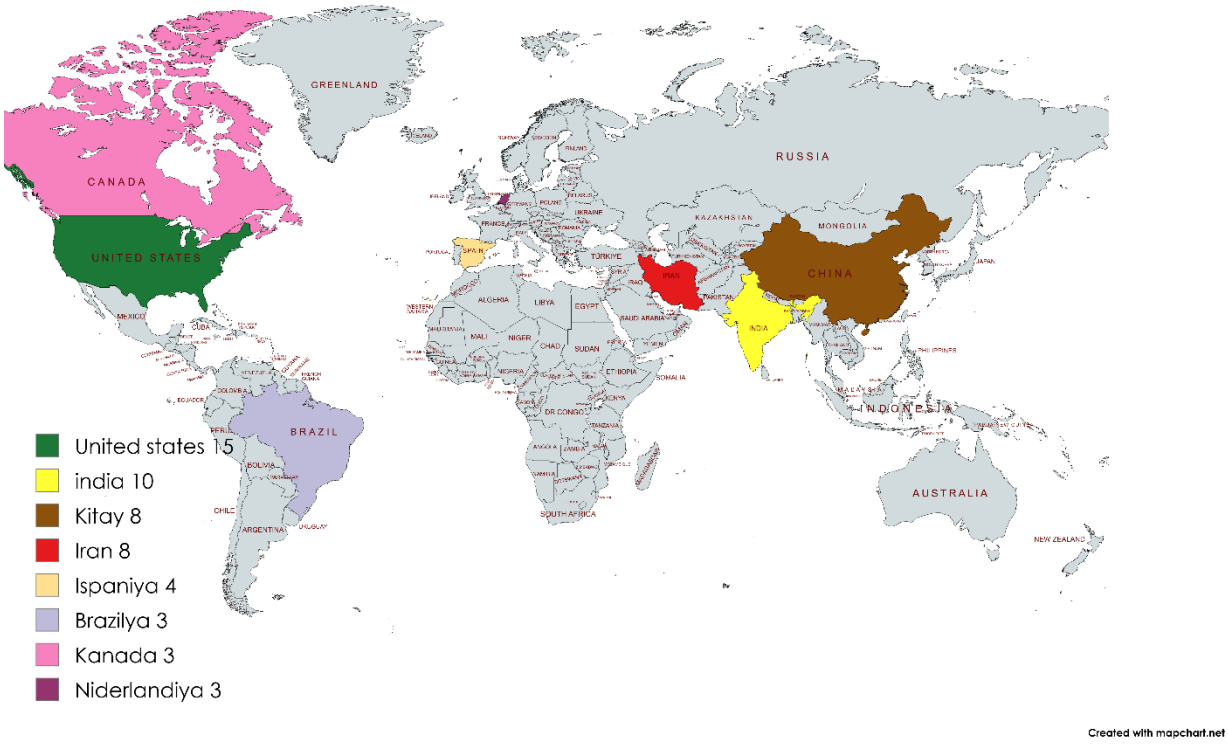

Figure 4. List of top countries on Internal water resources

3.4 Top cited papers on Internal water resources

Given is in the Table 1 which presents data concerning ten the mostly cited papers on Internal water resources in the different countries. Almost of citations given to 15 papers from the Table 2. First 15 top cited papers are consisting all 1161 articles.

Table 1. List of top cited publications Internal water resources

No.	*Title*	*Journal*	*Corresponding author*	*PY*	*TC 2000-2022*	*Doc.type*
1.	Effects of deficit irrigation on yield, water productivity, and economic returns of wheat	Agricultural Water Management	M.H., Ali, Md Hossain;	2007	239	Article
2.	An improved water use efficiency of cereals under temporal and spatial deficit irrigation in north China	Agricultural Water Management	Taisheng.T.	2010	209	Article
3.	MOPECO: An economic optimization model for irrigation water management	Irrigation Science	José Fernando.	2004	111	Article
4.	Modeling wheat yield and crop water productivity in Iran: Implications of agricultural water management for wheat production	Agricultural Water Management	Faramarzi.	2010	102	Article
5.	Water productivity of maize in the US high plains	Irrigation Science	Trout .	2017	97	Article

No.	Title	Journal	Corresponding author	PY	TC 2000-2022	Doc.type
6.	Using the SWAT model to assess the impacts of changing irrigation from surface to pressurized systems on water productivity and water saving in the Zarrineh Rud catchment	Agricultural Water Management	Ahmadzadeh.	2016	96	Article
7.	A multistage irrigation water allocation model for agricultural land-use planning under uncertainty	Agricultural Water Management	Dai.	2013	91	Article
8.	An interval multi-objective programming model for irrigation water allocation under uncertainty	Agricultural Water Management	M.W.	2018	81	Article
9.	Logistic model application for prediction of maize yield under water and nitrogen management	Agricultural Water Management	A.R.,	2011	69	Article
10.	Hydrological modelling of a small watershed using MIKE SHE for irrigation planning	Agricultural Water Management	R.P.,	1999	66	Article

* PY – Published year, * TC – Total citation

3.5 . Keyword and co-authorship network

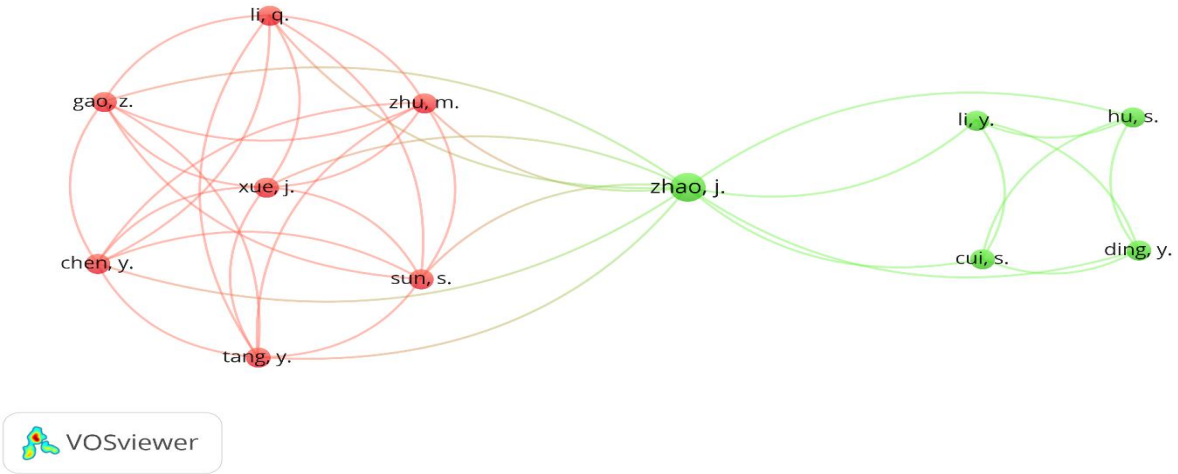

Figure 5. Network map of top co-authorships based on the total link strength.

No-authorship, keyword co-occurrences, citations, bibliographic coupling, and co-citation maps can be generated using VOSviewer based on bibliographic data. File formats supported include .txt, ris, and .csv from databases such as Scopus. The raw file was imported into VOSviewer and a map of co-authorship and keyword co-occurrences (shown in Figure 5, 6) were created using the software. The co-authorship analysis resulted in a network of 159 authors. Only authors having a minimum of two publications on the topic of water use were included.

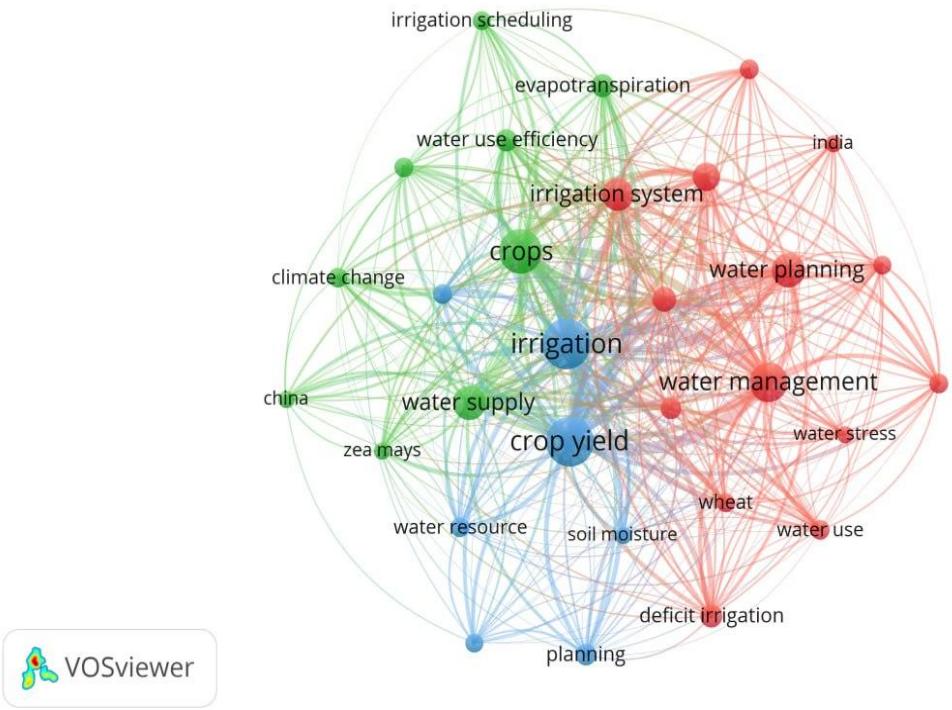

Figure 6. Network map of top keywords based on the total link strength

The analysis yielded 1107 keywords. After excluding the general keywords with a low relevance score and those with low occurrence (by default, a minimum of 60 occurrences of a keyword is selected, to strengthen the co-occurrence results), 30 items were finally identified. Based on the total link strength, each resulting keyword is sketched in a node, creating a network map of all keywords. Figure 6 shows the network map of the top 15 authors' keyword co-occurrence. The size of the node reflects the keyword's degree of importance. There are 30 items distributed over 3 clusters: cluster 1 (crop yield, defict irrigation, india, irrigation system, productivity, soil moisture, water conservation, water management, water planning, water productivity, water resources, water stress, water use, wheat, yield response), cluster 2 (china, climate change, crop production, crops, cultivation, evapotranspiration, irrigation, irrigation scheulding, optimization, water supply, water use efficiency, zea mays), cluster 3 (decision making, planning, water resource).

4.DISCUSSION

The bibliometric analysis of 53 Scopus-indexed publications on water use planning and water management from 1989 to 2024 revealed four major thematic clusters that define the evolution of global irrigation and water management research. These clusters differ in methodological focus, research depth, and policy relevance, reflecting how the field has diversified over the past three decades. The first cluster, field experiments on partial irrigation (8 papers), represents empirical studies evaluating the effects of reduced irrigation on crop performance and soil-water relations. Most experiments were conducted in arid and semi-arid regions such as China, Iran, and India, where water scarcity is a key limitation. Findings show that partial irrigation can maintain stable yields while reducing total water use by 30–40%,

which highlights its potential for optimizing water efficiency without compromising food security.

The second cluster, comparing full versus deficit irrigation on cereals and wheat (5 papers), analyzes yield response functions under different irrigation regimes. These studies compare the physiological and agronomic effects of full and deficit irrigation on major cereal crops. Results indicate that deficit irrigation, when properly timed and monitored, can achieve up to 85–90% of maximum yield while saving considerable water resources. This approach is increasingly recognized as a sustainable practice in water-stressed agricultural zones.

The third cluster, economic return and crop yield modeling (18 papers), integrates hydrological, agronomic, and economic perspectives. This is the largest thematic group, focusing on modeling tools such as Aquacrop, DSSAT, and SWAT to simulate crop yield, water productivity, and financial returns. Studies in this cluster demonstrate that integrating economic optimization into irrigation planning leads to more rational water allocation and higher resource-use efficiency.

The fourth cluster, others, consists of 24 papers covering topics such as water policy, climate adaptation, sustainability frameworks, and institutional governance. This cluster reflects the increasing relevance of interdisciplinary approaches linking hydrology, policy, and socio-economic systems. After 2015, with the adoption of the UN Sustainable Development Goals (SDGs), publications in this area have increased significantly, emphasizing the importance of cross-sectoral cooperation and adaptive water governance.

Overall, the analysis demonstrates a clear transition from small-scale field experiments to broader integrated frameworks combining technology, modeling, and policy perspectives. The diversity of research directions suggests that sustainable water management depends on both innovative irrigation practices and holistic socio-economic strategies. Strengthening data-driven approaches, international collaboration, and long-term monitoring will be essential for achieving future progress in global water resource management.

Table 2. Thematic Clusters and Key Research Streams in Irrigation Studies

Cluster	Dominant Keywords	Number of Articles	Key References (Author, Year)
Field experiments on partial irrigation	deficit irrigation; water productivity;drip irrigation; irrigation treatment; deficit irrigation; cotton yield; full irrigation, pomegranate orchard;nitrogen, winter wheat, semi-arid;deficit irrigation; peach trees; nitrogen fertilization; direct-seeded rice;	8	Ali & Hoque, 2007 Trout & DeJonge, 2017 Rao, Tanwar , 2016 Parvizi et al., 2014 Sepaskhah ;2006; Rufat, Josep, 2016 Bonfim-Silva, 2014 Deelstra et al., 2018
Comparing full vs deficit irrigation on cereals or wheat	deficit irrigation; water-use efficiency; deficit irrigation, cereals; yield; water use efficiency (WUE); sweet corn; green bean; actual crop yield;	5	Du, Kang, Sun, 2010 Author details missing from available preview Sun et al., 2022 Teshome et al., 2023 Panda & Inamdar, 2012
Economic return and crop yield modeling	economic optimisation model; irrigation water use; water-scarcity;	19	Ortega-Álvarez, 2004. Faramarzi, Yang, 2010 Ahmadzadeh, 2016

Cluster	Dominant Keywords	Number of Articles	Key References (Author, Year)
	simulation model,basin-scale irrigation multistage irrigation water allocation interval numbers; uncertainty; logistic model; maize yield prediction irrigated arid lands, crop yield, salinity, optimisation model, water allocation; optimization, costs & returns; AquaCrop model; irrigation schedules; full or deficit irrigation; lanning-level irrigation schedules; crop planning, agronomic yield; linear programming; cropping pattern; irrigated crop acreages; stochastic modelling; water-saving irrigation, crop yield; wheat; potato; earth observation;		Dai & Li, 2013 Li et al., 2018 Sepaskhah, 2011 Kandil et al., 1995 Reca, Roldán, 2001 Gilley & Supalla, 1989 Kale & Lokhande, 2017 Mancosu, Spano, 2016 (Brumbelow, 2007 Fazlali &Shourian, 2018 Prasad, Umahesh 2011 Asghari ,Shulstad, 1991 Ganji & Kaviani, 2013 Li & Zhao, 2025 Jaafar, Karimi, 2024
others	hydrological modelling; water requirement; summer maize; water scarcity, stochastic optimisation, water savings; crop yield; “evapotranspiration”, “crop coefficient value engineering; life-cycle cost; internal processes; hardware; climate change; spatial soil variability; remote sensing; economic indicators; soil water characteristics; fuzzy credibility constraints; regression models; sunshine hours; future climate scenarios; water scarcity; deficit irrigation;canal-command systems, AISSUM; system development; sodic groundwater, safe SAR value; farmland management; groundwater table depth; agricultural drought risk;	23	Singh, S, 1999 Yang, Gao, Shi, 2013 Schütze , 2010 Mason, Rufí-Salís,2019 Bezerra, da Silva, 2012 El-Nashar, 2022 Styles & Grismer, 2008 Soltani, Khalilian, 2020 Fulton et al., 2011 Soppe & Perry, 2010 Patil & Rajput, 2009 Wang C., & Huo Z, 2023 Singam,Kamasani, 2013 Miranda ,Cooke, 2018 Gunacti, 2018 Thorsen, 1997 Singh, 1995 Kaledhonkar et al, 2012 Huang, Cheng, 2018 Gul et al., 2024 Todisco et al., 2009

The bibliometric clustering presented above reveals four distinct, interconnected research streams that collectively shape scientific thinking on irrigation management, irrigation strategies, and water use optimization in agriculture. These clusters show the evolution from field-based agronomic experiments to advanced modeling, economic optimization, and climate-adapted water distribution systems, reflecting the pressures on freshwater resources and the need for data-driven planning in irrigated agriculture.

1. Field experiments on partial and deficit irrigation

The first cluster studies partial irrigation in field conditions. It is dominated by studies focusing mainly on cotton, wheat, orchards and rice. It introduces key terms such as partial irrigation, water efficiency, drip irrigation, nitrogen fertilization, semi-arid conditions and strong agronomic trends. Empirical experiments show that continuous controlled water reduction, combined with optimized nutrient management or efficient irrigation practices, can maintain acceptable yields. Within this cluster, crop responses to water stress are species-specific, with cotton and pomegranate showing relatively

high tolerance limits. Overall, this body of literature emphasizes physiological responses, soil-water dynamics, and crop-water relationships and provides a solid evidence base for further modeling research.

2. Comparative evaluation of full irrigation and deficit irrigation in cereal crops. The second cluster examines the balance between full irrigation and variable deficit irrigation regimes, with a reduced focus on cereal crops, particularly wheat, maize and sweet corn. The dominant keywords are water use efficiency (WUE), yield, actual yield and green bean/sweet corn, and the main focus is on determining the yield per unit of water used. Studies such as Du et al. (2010), Sun et al. (2022) and Teshome et al. (2023) consistently show that moderate deficit irrigation increases WUE without significantly reducing yields, especially in semi-arid regions.

This cluster builds a comparative evidence base supporting flexible irrigation scheduling, arguing that optimal water allocation requires consideration of crop sustainability and resource efficiency.

3. Economic returns, optimization and productivity modeling

The third cluster – the largest and most diverse – has significant implications for field-based, model-based, and analytical support systems. Dominant keywords include economic optimization models, simulation frameworks, logistic models, uncertainty-based allocation (interval numbers, stochastic modeling), yield prediction, and irrigation planning.

This body of research (e.g., Ortega-Alvarez, 2004; Faramarzi and Yang, 2010; Ahmadzadeh, 2016; Li et al., 2018; Jaafar and Karimi, 2024) has led to the evaluation of irrigation strategies at the farm, economic, watershed, and integrated levels. The overall conclusion of this cluster is that economic returns and water productivity can be maximized by dynamic, model-based water allocation strategies, especially in times of water scarcity.

This research stream offers robust tools for policy development, cropping pattern optimization, and long-term irrigation planning, demonstrating significant progress toward systematic and sustainable water management systems.

4. Broader research on hydrology, remote sensing and climate-responsive water management. A fourth cluster composed of diverse elements. Includes research on hydrological modelling, remote sensing, climate change impacts, channel systems, groundwater dynamics and risk-based tools. The set of keywords - water demand, evapotranspiration, soil spatial variability, AISSUM systems, climate scenarios, salinity, drought risk and value engineering - includes the integration of engineering, earth observation and environmental sciences into irrigation research.

Key works (e.g., Singh, 1999; Mason and Rufi-Salis, 2019; Fulton et al., 2011; Huang and Cheng, 2018; Gul et al., 2024) demonstrate the growing reliance on remotely sensed evapotranspiration and large-scale hydrological analyses. This cluster highlights the importance of technological innovation and system-wide monitoring in addressing future water scarcity, salinity, and climate variability. This cluster broadens the disciplinary scope of irrigation research, linking agronomy, hydrology, and climate modeling.

5.LIMATATIONS

The limitation of this study is that the analysis was based only on Scopus-indexed publications from 1989 to 2024. This method was selected to avoid potential formatting challenges that might arise when using data from multiple sources. However, this strategy restricts the study to English-language papers available in Scopus, thereby excluding relevant literature from other databases and in different languages. Future research could address this limitation by incorporating data from a range of databases and considering literature published in multiple languages.

6.CONCLUSION

This bibliometric study analyzed 53 Scopus-indexed publications related to water use planning and water management from 1989 to 2024. The results demonstrate that scientific interest in this field has grown significantly since 2005, coinciding with global awareness of water scarcity, climate change, and the need for sustainable resource management. The analysis identified four main thematic clusters that together reflect the evolution and diversification of water management research over the past three decades.

The first cluster, field experiments on partial irrigation, provided practical insights into optimizing limited water supplies under arid conditions. These studies proved that moderate water reduction can sustain acceptable yields while conserving substantial water volumes, making it an essential approach for dryland agriculture. The second cluster, comparing full versus deficit irrigation on cereals and wheat, showed that strategic deficit irrigation can achieve high yield efficiency with reduced water input, supporting sustainable intensification goals in agriculture.

The third and most extensive cluster, economic return and crop yield modeling, integrated biophysical and economic models to optimize water productivity and profitability. These studies highlight the growing importance of simulation tools and decision-support systems for efficient water allocation and sustainable crop management. The fourth cluster, encompassing policy, climate adaptation, and sustainability studies, emphasized governance mechanisms, adaptive management frameworks, and international collaboration as key elements for achieving long-term water security. Overall, the bibliometric results indicate a gradual transition from purely agronomic and technical studies to integrated, multidisciplinary approaches that combine environmental, economic, and policy perspectives. Future research should focus on the development of intelligent irrigation systems, real-time monitoring networks, and cross-sectoral policy frameworks that support climate-resilient water governance. Strengthening international cooperation, sharing open-access data, and expanding long-term field observations will be essential for addressing the global challenges of water management and for supporting sustainable development in both developed and developing regions.

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O‘ZBEKISTONDA SELLYULOZA PARCHALOVCHI QO‘ZIQORIN YETISHTIRISH, SUBSTRATLARI VA ULARNING SAMARADORLIGI

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Annotatsiya. *Ushbu maqolada tsellyuloza parchalovchi qo'ziqorinlarni yetishtirishning dolzarb masalalari, ularning oziq-ovqat xavfsizligi va qishloq xo'jaligi chiqindilarini qayta ishlashdagi ahamiyati yoritilgan. Qo'ziqorinlar tarkibida oqsil, vitaminlar va mineral moddalarning ko'pligi ularni inson ovqatlanishida muhim o'rin tutishini belgilaydi. Shuningdek, ular dorivor xususiyatga ega bo'lib, immunitetni mustahkamlashda qo'llaniladi.*

Tadqiqotda sifatli urug'lik mitseliy yetishtirish, genetik tozalik va mikroorganizmlardan holi bo'lish talablari ko'rib chiqilgan. Substrat tanlashning iqtisodiy samaradorlikka ta'siri, paxta sheluxasi, makkajo'xori poyasi, yeryong'oq po'chog'i, qizilmiya ildizi chiqindilari va yog'och qipig'idan foydalanish imkoniyatlari o'rganilgan. Qo'shma substratlardan foydalanish hosildorlikni 25-35% gacha oshirishi, mitseliy o'sishini tezlashtirishi va mahsulot tannarxini 30-40% ga kamaytirishi aniqlangan.

Maqolada qo'ziqorin yetishtirishning ekologik jihatlari, chiqindilarni qayta ishlash va ulardan biogumus olish orqali tuproq unumdorligini oshirish masalalari ham ko'rib chiqilgan. Shuningdek, Pleurotus ostreatus, Pleurotus eryngii, Lentinula edodes va Agaricus bisporus turlarining biologik xususiyatlari va yetishtirish texnologiyalari tahlil qilingan.

Kalit so'zlar: *tsellyuloza parchalovchi qo'ziqorinlar, substrat, mitseliy, hosildorlik, qishloq xo'jaligi chiqindilari, biogumus, oqsil,* Pleurotus ostreatus, *kompost, tannarx.*

Аннотация. *В данной статье освещены актуальные вопросы выращивания целлюлозоразрушающих грибов, их значение для продовольственной безопасности и переработки сельскохозяйственных отходов. Высокое содержание белков, витаминов и минеральных веществ в грибах определяет их важную роль в питании человека. Кроме того, они обладают лечебными свойствами и используются для укрепления иммунитета.*

В исследовании рассмотрены требования к выращиванию качественного посевного мицелия, его генетической чистоте и отсутствию микроорганизмов. Изучено влияние выбора субстрата на экономическую эффективность, возможности использования хлопковой шелухи, кукурузных стеблей, скорлупы арахиса, отходов корня солодки и древесных опилок. Установлено, что использование комбинированных субстратов повышает урожайность до 25–35%, ускоряет рост мицелия и снижает себестоимость продукции на 30–40%.

В статье также рассмотрены экологические аспекты выращивания грибов, переработка отходов и повышение плодородия почвы путём получения биогумуса. Проанализированы биологические особенности и технологии выращивания видов Pleurotus ostreatus, Pleurotus eryngii, Lentinula edodes *и* Agaricus bisporus.

Ключевые слова: *целлюлозоразрушающие грибы, субстрат, мицелий, урожайность, сельскохозяйственные отходы, биогумус, белок,* Pleurotus ostreatus*, компост, себестоимость.*

Abstract. *This article highlights the current issues of cultivating cellulose-degrading mushrooms, their importance for food security, and the processing of agricultural waste. The high content of proteins, vitamins, and minerals in mushrooms determines their significant role in human nutrition. Moreover, they possess medicinal properties and are used to strengthen the immune system.*

The study examines the requirements for growing high-quality spawn mycelium, including genetic purity and freedom from microorganisms. The impact of substrate selection on economic efficiency is analyzed, along with the use of cotton seed husks, corn stalks, peanut shells, licorice root waste, and wood sawdust. It has been found that using combined substrates increases yield by 25–35%, accelerates mycelium growth, and reduces production costs by 30–40%.

The article also covers ecological aspects of mushroom cultivation, waste recycling, and improving soil fertility through biogumus production. Biological characteristics and cultivation technologies of Pleurotus ostreatus, Pleurotus eryngii, Lentinula edodes, *and* Agaricus bisporus *species are analyzed.*

Keywords: *cellulose-degrading mushrooms, substrate, mycelium, yield, agricultural waste, biogumus, protein,* Pleurotus ostreatus, *compost, production cost.*

KIRISH

Aholi sonining ortishi, oziq-ovqat mahsulotlariga bo‘lgan talabning ko‘payishi hamda qishloq xo‘jaligi chiqindilarini ekologik xavfsiz qayta ishlash masalalari dunyo miqyosida muhim ahamiyat kasb etmoqda. Shu nuqtai nazardan sellyuloza parchalovchi iste’molbop qo‘ziqorinlar biotexnologiya, oziq-ovqat sanoati va qishloq xo‘jaligida istiqbolli biologik obyektlar hisoblanadi.

Sellyuloza parchalovchi Pleurotus ostreatus, Pleurotus eryngii, Lentinula edodes, Agaricus bisporus qo‘ziqorinlari hisoblanadi. O‘simlik chiqindilarida yetishtiriladigan qo‘ziqorinlar sellyloza parchalash xususiyatiga ega bo‘lib ular asosan o‘sib rivojlanish, hosildorligi oziqa muxitining taqkibidagi sellylozaga bog‘liq. Qo‘ziqorinlar iste’mol qilish bilan birgalikda ularda qayta ishlash yo‘li bilan vitamin,

oqsil, antibiotik, limon, sirka, glykon kislotalari olinadi. Bundan tashqari organiq o‘g‘itlar, tuproq unumdorligini oshirishda biogumuslar olishda foydalaniladi.

Hozirgi kunda sellyuloza parchalovchi qo‘ziqorinlar o‘simlik qoldiqlari tarkibidagi sellyuloza, gemitsellyuloza va lignin moddalarini fermentlar yordamida parchalash xususiyatiga ega. Ular somon, paxta chiqindisi, yog‘och qirindisi, makkajo‘xori poyasi kabi organik substratlarda o‘sib, ushbu chiqindilarni qimmatli oziq-ovqat mahsulotiga aylantiradi. Bunday qo‘ziqorinlarga Pleurotus ostreatus, Pleurotus eryngii, Lentinula edodes va Agaricus bisporus kabi turlar kiradi.

Ushbu qo‘ziqorinlar yuqori oziqaviy qiymatga ega bo‘lib, tarkibida oqsil, aminokislotalar, vitaminlar va mineral moddalar ko‘p miqdorda bor. Iste’mol qilinadiga qo‘ziqorinlat inson oziqasinig asosiy omillardan biri hisoblanadi. Bundan tashqari, ularning ayrim turlari dorivorlik xususiyatga ega bo‘lib, ulardan immunitetni mustahkamlash va organizm faoliyatini tiklashda muxim bo‘lgan antibiotiklar ajratib olinadi.

Sellyuloza parchalovchi qo‘ziqorinlar nafaqat oziq-ovqat mahsuloti, balki qishloq xo‘jaligi mahsulotlarini chiqindilarini biologik qayta ishlash, kompost va biogumus ishlab chiqarish, atrof-muhit ifloslanishini kamaytirish hamda biotexnologik mahsulotlar olishda ulardan foydalaniladi. Qo‘ziqorinlarni yetishtirish texnologiyalarini takomillashtirish bilan birgalikda ulardan, yuqori hosil olish, mahsuldorligi yuqori bo‘lgan shtammlarni ajratish, qo‘ziqorinlarni qayta ishlash hamda sanoat miqyosida ishlab chiqarishni kengaytirish dolzarb vazifalardan biri hisoblanadi.

sellyuloza parchalovchi qo‘ziqorinlarning biologik xususiyatlari, yetishtirish texnologiyasi, xalq xo‘jaligida, qishloq xo‘jaligida ahamiyati va ulardan samarali foydalanish imkoniyatlarini o‘rganishga dolzarb masalalardan biri hisoblanadi.

TADQIQOTNING MAQSADI. Qishloq xo‘jaligi chqindilaridan samarali foydalanish, ekologik muvozanatni saqlash va iqtisodiy foyda olishda muhim ahamiyatga ega mahsulotlar yetishtirish asosiq maqsad biri hisoblanadi. Pespublikamizda qo‘ziqorinchilikda istisoslashgan klaster va tashkilotlar mavjud emas. Yangi yo‘nalishlar bo‘lsa-da, iqlim sharoiti, xom ashyo ba’zasi va bozor ehtiyoji juda yuqori. Ammo bu sohada muvaffaqiyatga erishish uchun asosiy bosqich-sifatli urug‘lik mitseliy yetishtirish va samarali substrat tanlash hisoblanadi.

TADQIQOT OBYEKTI. Iste’mol qilinadigan qo‘ziqorinlarni sifatli uruglik mitseliysini yetishtirish. Respublikamiz sharoitida qo‘ziqorinchilikni rivojlantirish bilan birgalikda urug‘lik mitseliylarini yetishtirish. Patogenlik qiladigan mikroorganizmlarga qarshi kurash.

TADQIQOT PREDMETI. Qo‘ziqorin yetishtirish jarayonida muxim omillardan biri urug‘lik mitseliysini tayyorlash. Sifatli urug‘lik mitseliy bozor bop yuqori hosil, sifati kafolatgan mahsulotlar yetishtirish. Sifatsiz urug‘ ekilsa hosildorligi past hamda sifatsiz hosil olishga erishiladi.

TADQIQOT NATIJALARI

Urug‘lik mitseliy sifati-muvaffaqiyat kaliti

Sifatli urug‘lik mitseliy quyidagi xususiyatlarga ega bo‘lishi kerak:

Genetik tozalik: Mitseliy genetik jihatdan bir xil bo‘lishi, yuqori hosildor qo‘ziqorinlardan olingan bo‘lishi kerak.

Ifloslanmaganligi: Urug‘lik miseliy mikroorganizmlardam xoli bo‘lishi kerak.

Faol o‘sish qobiliyati: Mitseliy substratga tez moslashishi, o‘sishi samaradorlikgi yuqori bo‘lishi.

Urug‘lik mitseliysini saqlash: Urug‘lik mitseliy 20-250C haroratda saqlanadi muzlatilgan yoki juda issiq joyda saqlansa, faolligini yo‘qotishi mumkin.

Shu bois, qo‘ziqorin yetishtirishni boshlashdan avval, miseliy yetishtirish talablariga javob beradigan laboratoriya yoki yetakchi ishlab chiqaruvchilardan urug‘lik mitseliy harid qilish juda muhim. Urug‘lik sifatini nazorat qilish barqaror hosil va iqtisodiy samaradorlikningning asosiy kafolatidir.

Substrat tanlovi: Tannarxni pasaytirishning asosiy yo‘li

Respublikamizda qo‘ziqorin yetishtiruvchilar asosan paxta chiqindilari va boshoqli don ekinlari chiqindilaridandan foydalanadilar. Qo‘ziqorinlarni yetishtirishda asosan qishloq xo‘jaligi mahsulotlarining chiqindilaridan foydalaniladi. Qo‘ziqorin yetishtirsh chiqindisiz mahsulotlar yetishtirish texnologiyasi hisoblanadi. Shu sababli, sellyulozaga boy chiqindilardan: makkajo‘xori poyasi, so‘tasi, kungaboqar poyasi, qizilmiya ildizi, yeryong‘q po‘chog‘i, yog‘och qipig‘i (opilka), boshoqli don ekillari somoni chiqindilaridan foydalaniladi.

Substratlarni tanlashdan asosiy maqsad mahsulot tan narxini arzon bo‘lishi va sifatli hosil olish.

Qo‘ziqorin yetishtiriladigan substratlar urug‘lik miseliy tez o‘sishi, hosil o‘sishi, hosildorligi yuqori bo‘lishi eng muhim omlillardan biridir. Substrat nafaqat qo‘ziqorin hosildorligiga, balki mahsulot tannarxiga ham ta’sir qiladi. Arzon va oson topiladigan xomashyoni tanlash iqtisodiy samaradorlikka erishishga muhim ahamiyatga ega.

Respublikamiz sharoitida qo‘ziqorin yetishtiruvchilar asosan chigit sheluxasidan eng ko‘p foydalanadilar. Chigit sheluxasi topilishi oson barcha vilotlarda bor arzon, keng tarqalgan va sellyulozaga boy bo‘lgani uchun yaxshi hosildorliq yuqori bo‘ladi. Biroq, faqat shu bilan cheklanish shart emas.

Sellyuloza parchalovchi qo‘ziqorinlar masalan, Shimeji, Pleurotus eryngii, Pleurotush ostreatusturlari uchun quyidagi alternativ substratlar ham mavjud:

Makjoxo‘ri so‘tasi va poyasi: Qishloq xo‘jaligidagi chiqindi sifatida ko‘p uchraydi. Sellyuloza miqdori yetarli va arzon.

Yeryong‘oq po‘chog‘i va poyasi: Xususan yeryong‘oq yetishtiriladigan hududlarda ko‘p miqdorda chiqindi hosil bo‘ladi. Ximiyaviy ishlovdan o‘tkazilsa, yaxshi substrat bo‘ladi.

Qizilmiya ildizining chiqindlari: Farmatsevtika va ekstrakt ishlab chiqarishdan qolgan bu modda ham minerallarga boy va mitseliy o‘sishiga mos muhit bo‘la oladi.

Yog‘och qipig‘i (opilka): Ayniqsa mevador yoki yong‘oq daraxtlaridan olingan opilka qo‘ziqorinlar uchun maqbul hisoblanadi.

Sholi qipig‘i eng arson deyarli ishlatilmaydigan substarlar hisoblanadi.

Ushbu substratlardan foydalanish nafaqat chiqindilarni qayta ishlashga yordam beradi, balki qo‘ziqorin yetishtirishda tannarxni sezilarli pasaytirish, ishlab chiqarishni kengaytirish va atrof-muhitga zarar yetkazmaslik imkonini ham beradi.

Qo‘shma substratlardan foydalanish samarasi

Qo‘ziqorin yetishtirishda mitseliy o‘sishi va hosildorlik darajasi katta qismda substratning tarkibiga bog‘liq. Bir turdagi substratdan foydalanish ko‘p hollarda samara bersa-da, uni boshqa moddalar bilan aralashtirish, ya’ni qo‘shimcha substratlar tayyorlash, yetishtirish jarayonini yanada samarali bo‘lishiga xizmat qiladi.

Qo‘shimcha substratlar: ikki yoki undan ortiq turdagi xomashyoni aralashtirish orqali tayyorlanadigan substratlar yoqori hosilning garovidir.

Qo‘shimcha substarlarning asosiy afzalliklari:

Ximiyaviy tarkibni muvozanatlash: qishloq xo‘jalik mahsulotlarini chiqindilarga boy turli substratlar tayyorlash. paxta sheluxasi sellyulozaga boy bo‘lsa, makkajo‘xori so‘tasi va poyasi gemitsellyuloza va mineral moddalar ko‘p hisoblanadi. Aralashtirish natijasida yuqori hosil olish uchun substratlar tayyorlanadi.

Mitseliy o‘sishini tezlashtirish: turli ekillarni chiqindilari aralashtirilgan substratlar mitseliyning tez moslashishi va jadal o‘sishini ta’minlaydi.

Hosildorlikni oshirish: Substratlar sifatli bo‘lsa qo‘ziqorinning hosili ham yuqori bo‘ladi. Bir xil turdagi substartlarda hosil 15-20% atrofida bo‘lsa, aralsh substratlarda bu ko‘rsatkich 25-35% gacha oshishi kuzatilgan.

Qimmat substratni arzon chiqindilar bilan aralashtirish orqali tannarxni pasaytirish mumkin.

Masalan:

Chigit sheluxasini + yog‘ch qipig‘I bilan aralashtirish.

Makkjo‘xori so‘tasi va poyasini + yeryong‘oq po‘chog‘i hamda poyasi bilan aralashtirish.

Qizilmiya chiqindisi + chigit sheluxasi bilan aralshtirish.

Qo‘shma substratlardan foydalanish nafaqat qo‘ziqorin hosilini oshiradi, balki ishlab chiqarishdagi barqarorlikni ta’minlab, chiqindilarni qayta ishlashga ham hissa qo‘shadi.

Bir nechta chiqindilarni aralashtirish orqali qo‘ziqorin mevatanasini oshirish, fruktefikatsiya davrini qisqartirish va xarajatlarni kamaytirish mumkin. Masalan, 70% makkai so‘tasi + 30% yeryong‘oq po‘chog‘i aralashmasi samarali hisoblanadi.

Iqtisodiy va ekologik afzalliklar

Iqtisodiy jihatdan: chiqindilarni qo‘shma substrat sifatida ishlatish tannarxni 30-40% ga pasaytiradi va ish o‘rinlari yaratadi. Ekologik jihatdan: chiqindilar qayta ishlanadi, tabiatga zarar kamayadi va qoldiqlar organik o‘g‘it sifatida foydalaniladi.

XULOSA

Pespublikamizda sellyuloza parchalovchi qo‘ziqorinlarni yetishtirish sohasida rivojlanish oziq-ovqatga bo‘lgan talabni qondirish. Qishloq xo‘jaligi chqindilarini aralshtirish hisobida yuqori hosildorlikka erishim. Qo‘iqorinlarni yetishtirshda substrat sifatini oshirish bilan birga ularni hosildorligi ham oshadi. Chiqindi sifatifa tashlab yuboradigan mahsulotlardan hosil olish, olingan hosildan qolgan chiqindilarni

biogumisga aylantirsh va tuproq unimdorligini oshirishda qaratilgan muammolarni bartaf etish.

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DO‘LANA (CRATAEGUS PONTICA L.) MEVALARIDAN MARMELAD TAYYORLASH TEXNOLOGIYASI

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Annotatsiya. *Mazkur maqolada sariq do‘lana mevasi dorivor hamda ozuqaviy qiymati jihatidan yuqori bo‘lgan tarixiy ahamiyatga ega bo‘lgan meva hisoblanib, dunyoning ko‘pgina mamlakatlarida uni tabiiy holda o’sishi, undan qayta ishlab marmelad olish jarayoni, do’lana mevasining kimyoviy tarkibidan kelib chiqib, turli xil oziq ovqat mahsulotlari ishlab chiqarish imkoni borligi tasdiqlangan. Do’lanani kimyoviy tarkibi jihatidan, ozuqalilik ko‘rsatkichlari bo‘yicha yuqori darajada ekanligi o‘rganilib, bugungi kunda respublikamiz aholisi tomonidan iste’mol usullari va do’lana mevasidan marmelad olish bo‘yicha ilmiy asoslangan ma’lumotlar keltirilgan.*

Kalit so‘zlar. *Crataegus pontica L., sariq do’lan mevasi, kimyoviy tarkibi, ozuqalik xususiyatlari, qayta ishlash, marmelad, texnologik jarayonlar, quritish, tayyor mahsulotlar.*

Аннотация. *В данной статье рассматриваются плоды желтого боярышника как исторически ценный продукт с высокой лекарственной и питательной ценностью. Подтверждена возможность производства различных видов пищевой продукции на основе химического состава боярышника, приведены данные о его естественном произрастании во многих странах мира, а также технологический процесс переработки плодов для получения мармелада. В ходе исследования были изучены высокие показатели питательности и химического состава боярышника. Кроме того, представлены научно обоснованные данные о способах его употребления населением нашей республики и технологии производства мармелада из плодов боярышника.*

Ключевые слова. *Crataegus pontica L., плоды желтого боярышника, химический состав, питательные свойства, переработка, мармелад, технологические процессы, сушка, готовая продукция.*

Abstract. *This article highlights the yellow hawthorn fruit (Crataegus) as a historically significant product with high medicinal and nutritional value. Based on its chemical composition, the study confirms the potential for manufacturing various food products from this fruit, detailing its natural habitat across many countries and the*

technological process of processing it into marmalade. Furthermore, the high nutritional profile and chemical constituents of hawthorn were evaluated, providing scientifically proven data on its current consumption patterns among the population of our republic and the innovative methods of marmalade production.

Keywords. *Crataegus pontica L., yellow hawthorn fruit, chemical composition, nutritional properties, processing, marmalade, technological processes, drying, finished products.*

KIRISH

Do‘lana (*Crataegus pontica L.*) tarqalish maydoni Markaziy Osiyoning tog‘li va tog‘oldi hududlarida keng tarqalgan. O‘zbekistonning tog‘li hududlari, xususan, Toshkent viloyati, Jizzax viloyati, namangan viloyati va bir qancha tog‘li hududlarimizda ham do‘lananing sariq hamda qizil turlarini uchratishimiz mumkin. Do‘lana dorivorlik jihatidan hamda ozuqaviy qiymati jihatidan yuqori bo‘lgan tabiiy holda o‘sadigan o‘simlik hisoblanadi. Do‘lana mevalari mevalari tarkibida inson salomatligi uchun zarur bo‘lgan bir qancha biologik faol moddalarni uchratishimiz mumkin, jumladan vitaminlar, organik kislotalar, pektin moddalari, flavonoidlar va antioksidantlar shular jumlasidandir. Ayniqsa, do‘lana mevalari tarkibidagi pektin moddalarining yuqoriligi do‘lana mevalarining qandolat sanoatida, xususan, jele va marmelad mahsulotlari ishlab chiqarilishida qimmatli xomashyo turidan biri hisoblanadi.

Marmelad — bu meva va rezavorlar pyuresidan shakar qo’shilgan yoki aksincha shakarsiz holda jelelanuvchi (qumoqlantiruvchi) moddalar hamda organik kislotalar qo’shilgan holda mahsulotni qaynatish orqali tayyorlanadigan, pishiq konsistensiyali qandolat mahsulotidir.

METOD VA USULLAR

Biz ushbu maqolamizda laboratoriya sharoitida 5 kg do‘lana xomashyosidan foydalangan holda marmelad tayyorlash texnologiyasini optimallashtirish, 5 kg do‘lanadan tayyor mahsulotning chiqishi, tayyor bo’lgan mahsulotning fizik-kimyoviy hamda organoleptik ko‘rsatkichlarini o’rganib chiqdik.

Do‘lana mevalari do‘lanazorlardan qayta ishlash uchun pishib yetilgan davrda terib olinadi. Ushbu tadqiqotda obekt sifatida Toshkent viloyati Bo‘stonliq tumanida tabiiy xolda uchraydigan sariq do‘lana mevalari tanlab olingan. Bundan tashqari yordamchi materiallar sifatida shakar, quyultiruvchi modda (jelatin), kislotalikni muvozanatlash uchun limon kislotasi va ichimlik suvi olingan.

Har qanday qayta ishlanadigan mahsulotni qayta ishlashdan oldin biokimyoviy tarkibi o‘rganiladi. Biokimyoviy tarkib mahsulotning texnologik xususiyatlarini belgilab beradi. Laboratoriya tadqiqotlarida foydalanilgan sariq do’lana mevalarining o‘rtacha kimyoviy tarkibi tahlil qilinganda, uning tarkibida organik kislotalar, eruvchan quruq moddalar hamda pektinga boy ekanligi aniqlangan. Do’lana mevalari tarkibida asosan olma va limon kislotalari mavjud. Mahsulot tarkibidagi eruvchan quruq moddalar (EQM) miqdori refraktometr uskunasida tekshirilganda, do’lana mevalarining pishib yetilish darajasiga qarab 14% dan 18% gacha o‘zgarib turishi kuzatildi. Do’lana mevasining pektinga boyligi undan marmelad tayyorlash jarayonida

judayam qo‘l keladi. Pektin moddasining ko‘pligi hisobiga marmelad tayyorlash jarayonida unga shakar qo’shmasdan ham tayyorlash mumkin. Pektinning jelelanish xususiyati marmeladning tayyor bo‘lishida bosh rolni o‘ynaydi. Sariq do‘lana tarkibida protopektin (erimaydigan shakli) va gidropektin (eriydigan shakli) umumiy miqdori 1.2% dan 1.8% gacha yetadi. Bu ko‘rsatkich tashqi tomondan jelelovchi moddalar (masalan, agar-agar yoki tijorat pektini) qo‘shish miqdorini kamaytirish yoki umuman qo‘shmaslik imkonini beradi.

1-jadval.

5 kg do‘lana mevalaridan marmelad tayyorlashda unga ketadigan qo‘shimcha xomashyolar, ularning miqdori, tayyor mahsulotdagi ulushi va texnologik vazifasi.

№	Mahsulot nomi	Miqdori (kg / g)	Retsepturadagi ulushi (%)	Texnologik vazifasi
1.	**Sariq do‘lana mevasi**	5.0 kg	53.2%	Asosiy xomashyo, ta’m va rang beruvchi, tabiiy pektin manbayi
2.	**Shakar (Saxaroza)**	3.5 kg	37.2%	Shirinlik darajasi, konsistensiyani shakllantirish, EQMni oshirish
3.	**Agar-agar (yoki jelatin)**	0.08 kg (80 g)	0.85%	Qo‘shimcha jelelovchi, pishiq struktura hosil qiluvchi
4.	**Limon kislotasi (E-330)**	0.02 kg (20 g)	0.21%	pH muhitini sozlash (3.0-3.2), pektinning jelelanishini faollashtirish
5.	**Suv (Distillangan)**	0.8 litr	8.5%	Pyurening kuyishini oldini olish va agar-agarni eritish uchun
6.	**Jami xomashyo aralashmasi**	**9.4 kg**	**100%**	Pishirish jarayonigacha bo‘lgan umumiy massa

Marmelad tayyorlash jarayonida asosiy xomashyo sifatida sariq do‘lana mevalaridan 5 kg (retsepturadagi mahsulotning 53.2 %), qo‘shimcha mahsulotlardan shakar 3.5 kg (retsepturadagi mahsulotning 37.2 %), agar-agar yoki jelatin 80 g (retsepturadagi mahsulotning 0.85 %), limon kislotasi 20 g (retsepturadagi mahsulotning 0.21 %), suv 0.8 litr 8.5%(retsepturadagi mahsulotning 8.5 %) miqdorida olamiz. Har bir olgan mahsulotimizning o‘ziga xos bo‘lgan texnologik vazifalarga ega. Mahsulot tarkibiga qo‘shilgan shakar mahsulotning shirinlik darajasi shakllantirish, konsistensiyani shakllantirish hamda EQMni oshirish vazifasini bajaradi. Agar-agar (yoki jelatin) pishiq struktura hosil qilishda ishtirok etadi. Limon kislotasi pH muhitini sozlash (3.0-3.2) hamda pektinning jelelanishini faollashtiradi. Suv pyurening kuyishini oldini olish va agar-agarni eritish uchun ishlatiladi.

Marmeladni tayyorlash jarayoni bir qancha texnologik jarayonlarni o‘z ichiga oladi. Mahsulotni tayyorlashda har bir jarayon muhim hisoblanadi. Jarayonning ketma ketligiga amal qilish mahsulotning sifatli chiqishini belgilab beradi.

Dastlab keltirilgan sariq do‘lana mevalarini mexanik aralashmalardan tozalanib, bandlaridan ajratib olinadi. Saralab olingan mevalar sovuq oqib turgan suvda tozalab yuviladi. Yuvilgan mahsulotlar suvi laboratoriya elaklarida sirqitiladi.

Keyingi jarayon blanshirlash jarayoni hisoblanadi. Bunda mevalar laboratoriya qozoniga solinib, ustiga 0.5 litr suv qo‘shiladi. Meva eti yumshaguncha va protopektin eruvchan pektinga o‘tguncha bug‘ yoki past olovda blanshirlanadi. So‘ngra mevalar elakdan (teshigi d=1.0-1.5 mm) o‘tkazilib, danagi va po‘stlog‘idan ajratilgan toza pyure (o‘rtacha 3.8 kg) olinadi. Blanshirlash jarayonida suv harorati 95-100°C tashkil etadi. Bu jarayonga 15-20 daqiqa vaqt sarflanadi.

1-rasm. Mahsulotni yuvish jarayoni.

2-rasm. Do’lananing ajratilgan po’sti va danagi

80 g agar-agar 300 ml sovuq distillangan suvda 30 daqiqa davomida bo‘ktiriladi. Keyin sekin 20-60°C gacha qizdirilib, to‘liq eriguncha 30 40 daqiqa aralashtiriladi.

Meva pyuresi laboratoriya qozoniga olinadi, ustiga shakar qo‘shiladi va aralashtirib turilgan holda 102-105°C haroratda 25-30 daqiqa qaynatiladi. Qaynash ohirida erigan agar-agar eritmasi qo’shiladi. Eruvchan quruq moddalar miqdori refraktometrda o’lchanganda 65-68% ga yetganda mahsulot olovdan olinadi. Tayyor massa 80°C gacha sovutiladi va unga 20 g limon kislotasining suvli eritmasi qo‘shiladi (bu bosqichda pH 3.1 ga keltiriladi). Tayyor qaynoq massa maxsus silikon yoki metall qoliplarga quyiladi. Marmelad 20-22°C xona haroratida 4-6 soat davomida sovutiladi. Bu vaqtda mahsulotda jelelanish jarayoni sodir bo‘ladi. Malum vaqtdan keyin qoliplardan ajratilgan marmelad bo‘laklari laboratoriya sharoitida, suniy quritish pechlariga 40°C haroratda 24 soatga quritishga qo‘yiladi. Marmeladning namligi 20-22% gacha tushguncha quritiladi, so‘ngra germetik idishlarga qadoqlanadi.

3-rasm. Tayyor bo'lgan marmelad

4-rasm. Marmeladni konvektiv pechga quritishga qo'yish jarayoni

Natija. Marmelad namunalari tayyor bo'lgandan keyin, laboratoriyada standart talablari (GOST) asosida ularning asosiy fizik-kimyoviy ko'rsatgichlari tahlil qilindi.

2-jadval.

Tayyor marmeladning sifat ko'rsatkichlari.

№	Parametr nomi	Aniqlangan qiymat	Standart talabi (Meyor)	Tahlil usuli
1	**Eruvchan quruq moddalar (EQM)**	67.5%	Kamida 65.0%	Refraktometrik
2	**Namlik miqdori**	21.4%	20.0% - 24.0%	Quritish javonida vazn yo'qotish
3	**Umumiy kislotalilik (olma kislotasiga nisbatan)**	0.85%	0.6% - 1.2%	Titrimetrik (0.1 N NaOH bilan)
4	**Vodorod ko'rsatkichi (pH)**	3.15	3.0 - 3.3	Potensiometrik (pH-metr)
5	**Shakar**	8.2%	7.0% - 12.0%	Bertran usuli

pH qiymatining 3.15 atrofida bo'lishi pektin-shakar kompleksining optimal panjarali (gel) strukturasini hosil qilishi uchun ideal muhit hisoblanadi. Agar pH 3.5 dan yuqori bo'lsa, marmelad shaklini ushlay olmaydi (suyuq qoladi), 2.8 dan past bo'lsa, "sinerezis" (geldan suv ajralib chiqishi) hodisasi kuzatiladi.

5 kg boshlang'ich xomashyodan foydalanilganda har bir texnologik bosqichda sodir bo'ladigan massaning kamayishi va yakuniy tayyor marmeladning chiqishi quyidagi nisbatda taqsimlanadi.

Boshlang'ich 5 kg butun do'lana mevasidan danaklari va po'stloq qismi ajratilgandan keyin 3.8 kg pyure qoladi. Bu umumiy massaning 76 % ni tashkil etsa; ajratilgan danak, po'sloq va mexanik yo'qotishlar umumiy massaning 24 % ni tashkil etadi. Pishirish jarayonida umumiy massaning taxminan 30-32% gacha suvi bug'lanib ketadi, namlikning bug'lanishi va qo'shimcha mahsulotlarning qo'shilishi natijasida yakuniy tayyor quritilgan marmelad miqdori o'rtacha 5.2 kgni tashkil etadi.

Tayyorlangan do'lana marmeladi laboratoriya ekspertlari tomonidan 5 balli tizimda baholandi. Baholash jarayonlarida mahsulotning tashqi ko'rinishi, ya'ni shakli aniq, qirralari silliq, yuzasi shishasimon va tiniq ekanligiga 4.9 ball; konsistensiyasi-plastik, pishiq, kesilganda qisarsiz va cho'ziluvchan bo'lmagan zich struktura 4.8 ball;

rangi- sariq do‘lanaga xos bo‘lgan tillarang-jigarrang tusda, bir xil taqsimlanganligiga 5.0 ball;, hidi va ta'mini do‘lana mevasiga xos bo‘lgan yoqimli nordon-shirin ta'm, o‘ziga xos tabiiy xushbo‘ylik hamda shakar ta'mi meva kislotasi bilan to‘liq balanslashganligi 4.9 ball bilan baholandi.

XULOSA

Laboratoriya sharoitida o‘tkazilgan tadqiqotlar shuni ko‘rsatdiki, *Crataegus pontica L.* (Sariq do‘lana) mevalari o‘zining yuqori pektinlik va kislotalilik xususiyati bilan sifatli marmelad olish uchun mukammal xomashyo bazasi bo‘la oladi. Ishlab chiqilgan texnologik rejim (102-105°C pishirish harorati va pH 3.15 muhiti) mahsulot tarkibidagi vitaminlar va biologik aktiv moddalarni maksimal darajada saqlab qolish bilan birga, yuqori organoleptik ko‘rsatkichlarga ega barqaror strukturali marmelad olish imkonini berdi. Ushbu texnologiya asosida kelgusida qandolat sanoatida parhezbop va funksional oziq-ovqat mahsulotlari ishlab chiqarishni sanoat miqyosida yo‘lga qo‘yish tavsiya etiladi.

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DO‘LANA (CRATEAGUS PONTICA L)NING AGROBIOLIGIK XUSUSIYATLARI

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Annotatsiya. *Maqolada do‘lana (Crataegus L.) turkumi vakillari va ularning keng tarqalgan muxim turlari, biologiyasi, ekologiyasi va xalq xo‘jaligidagi axamiyati xaqida ma’lumotlar keltirilgan. Dulananing Jung‘or, Oltoy va sariq do‘lana turlari dorivor va oziq-ovqat axamiyatiga ega bo‘lib, ularni madaniylashtirish va plpntatsiya o‘stirish agrotexnikasini ishlab chiqish bugungi kundagi dolzarb masalalar hisoblanadi.*

Kalit so‘zlar. *do‘lananing turlari, tarqalish areali, o‘sish sharoiti, biomorfologik ko‘rsatkichlari, ayrim turlarining biokimyoviy tarkibi va ularning ahamiyati xaqida ma’lumotlar keltirilgan.*

Аннотация. *В статье представлены сведения о представителях рода Боярышник (Crataegus L.), их наиболее распространенных важных видах, биологии, экологии и значении в народном хозяйстве. Такие виды, как боярышник джунгарский, алтайский и желтый (понтийский), обладают высокой лекарственной и пищевой ценностью. В связи с этим разработка агротехники их введения в культуру и создания плантаций является одной из актуальных задач на сегодняшний день.*

Ключевые слова*. В работе представлены сведения о видах боярышника, ареале их распространения, условиях произрастания, биоморфологических показателях, биохимическом составе отдельных видов и их значении.*

Abstract. *The article provides information on the representatives of the hawthorn genus (Crataegus L.), their widely distributed essential species, biology, ecology, and significance in the national economy. Species such as Dzungarian, Altai, and yellow (Pontic) hawthorn possess substantial medicinal and nutritional value; therefore, introducing them into cultivation and developing agrotechnical methods for plantation growth represent urgent tasks today.*

Keywords. *The paper provides comprehensive data on the species of the genus Crataegus L., including their distribution areas, growth conditions, biomorphological characteristics, the biochemical composition of certain species, and their overall significance.*

KIRISH

Do‘lana (Crataegus L.) turkumiga 700 dan ortiq turi bo‘lib, ularning ko‘pchiligi Shimoliy Amerikada tarqalgan. Ular daraxt va buta o‘simliklaridir. Daraxtlarning balandligi 10-15 m ga, butalarining balandligi esa 0,5-4 m gacha yetadi. Ular bir tanali va ko‘p tikanli bo‘ladi, daraxt shakllari sershox. Po‘stlog‘i avval silliq, tiniq, kul rang, katta yoshida bo‘yiga yorilgan bo‘ladi, po‘stlog‘i to‘kilib turadi.

MDH mamlakatlarida 39 turi bo‘lib, ular orasida keng tarqalgan jung‘or do‘lanasi (Crataegus songorica C.Koch.) tog‘larning o‘rta qismida o‘sadi, Markaziy Osiyo va Qozog‘iston tog‘ daryolari havzalarida ko‘plab o‘sadi. Balandligi 5 metrgacha, shox-shabbalari yaxshi rivojlangan kichik daraxt. Novdalari uzunligi 15 mm gacha bo‘lgan jigarrang tikonlar bilan qoplangan. Barglari oval-rombsimon, asosi keng, chekkalari tishli, mevalari sharsimon, 13 mm diametrli to‘q qizil 3-4 tadan danakchalari mavjud. Mevasi to‘q sariq unsimon, iste’mol uchun yaroqli.

Oltoy do‘lanasi (Crateagus pontica L)Oltoy, Tyan-Shan, Pomir-Oloy tog‘larida va MDH ning Yevropa qismida keng tarqalgan. Pomir-Oloyda 1500-3000 metr balandliklarda toshloq va qumloq yerlarda o‘sadi. Sof do‘lanzorlar tashkil etmaydi, aksincha archa, qayin, qatrang‘i turlari bilan aralash o‘sadi. O‘rmon melioratsiyasi uchun juda qimmatli daraxt turi hisoblanadi.

1-rasm. Sariq do‘lana

1-rasm. Qizil do‘lana

METOD VA USULLAR

O‘zbekiston florasida do‘lananing bir nechta turlari mavjud. Ulardan 2 turi Pontiya yoki sariq do‘lana (Crateagus pontica L) va Turkiston yoki sariq va qizil do‘lana (Crataegus turkestanica Pojark.) keng tarqalgan.

Sariq do‘lana (Crateagus pontica L) balandligi 5-10 metrgacha, diametri 35 sm bo‘lib, tanasining po‘stlog‘i kulrang, jigarrangda. Ko‘plab yo‘g‘on tikonlar uchraydi, ularning uzunligi 1 sm gacha yetadi, keng shox- shabbali daraxt. U iyun oyida gullaydi, mevasi sentabr – oktabr oylarida pishib yetiladi. Asosan dengiz satxidan 1000-2000 metr balandlikdagi toshli tog‘ yonbag‘irlarida o‘sadi. Quruq tog‘ yonbag‘irlarida alohida-alohida, ba’zan kichik do‘lanazor hosil qilib o‘sadi. Respublikamizning barcha

viloyatlaridagi tog‘larida tarqalgan. Sariq do‘lananing bu biologik xususiyati qurg‘oqchilikni osonlik bilan o‘tkazishini ta’minlaydi. Birinchi yili sekin o‘sadi, u asosan urug‘idan ko‘payadi.

Sariq do‘lana istemol qilinadigan va dorivor o‘simlik. mevasining tarkibida 20% qand, 8% yog‘, flavonoidlar, vitaminlar, organik kislotalar bor. Xalq tabobatida sariq do‘lanadan aqliy toliqqanda, uyqusizlikda, yurak faoliyatini yaxshilashda foydalaniladi[2].

Do‘lana avvalambor dorivor o‘simlik sifatida yaxshi o‘rganilgan. Davolash maqsadida uning yangi terilgan yoki quritilgan mevalari ishlatiladi. Mevalari kuzda to‘liq pishib yetilgach, sovuqlar tushishiga qadar terib olinadi.

Do‘lananing mevasi istemol qilinadi, undan murabbo va sharbatlar xam tayyorlanadi. Turkiston yoki sariq do‘lana (Crateagus pontica L) balandligi 3-7 metrgacha yetadigan tikanli yirik buta yoki daraxt. Aprel-may oylarida gullab, mevasi sentabr-oktabr oylarida pishadi.

O‘zbekistonning deyarli barcha tog‘li xududlarida o‘sadi. U asosan toshloq tog‘ yonbag‘irlarida, daralar tubida, dengiz sathidan 2000 metrgacha bo‘lgan balandliklarda tabiiy o‘sadi. Tabiatda 8 metrgacha balandlikka ega, daraxtning tana po‘stlog‘i va novdalari to‘q kulrangda. Novda tikonlari 1,5 mm gacha bo‘lib, siyrak joylashgan. Daraxtdagi barglari ikki xil gulli o‘suvchi novdalarda kengroq uch bo‘lakli bo‘ladi.

Birinchi gullash 5-8 yoshli daraxtlarda kuzatiladi. Gullari yarim zontiksimon oq rangda, mevasi oktabrda yetiladi, mevasi tuxumsimon diametri 12 mm gacha, qizil, yaltiroq, sariq unsimon iste’molga yaroqsiz meva etiga ega, bir danakli.

NATIJA

Do‘lananing halq xo‘jaligidagi ahamiyati katta, undan har xil maqsadlar uchun foydalanish mumkin. U aholi yashash joylarini ko‘kalamzorlashtirishda to‘da-to‘da yoki qator qilib ekiladi. Parklarga ko‘pincha yarim yumshoq do‘lana (Crateagus pontica L) turi ko‘p ekiladi. Ular oval shaklidagi chiroyli shox- shabbasi va yirik mevalari bilan ayniqsa ko‘zga tashlanadi.

Do‘lananing pushti rang, qat-qat gulli shaklini (Crateagus pontica L) istiroxat bog‘larida ekish maqsadga muvofiq. Shaharlar atrofida yashil zonalar barpo etish uchun do‘lananing Oltoy do‘lanasi (Crataegus altaica Lange.), Hisor do‘lanasi (Crateagus pontica L.) sariq mevali do‘lana (Crataegus pseudoazarolus L.), Pontiya do‘lanasi (Crataegus pontica C.Koch.) turlarini ekish kerak. Bu turlar qurg‘oqchilikka chidamli bo‘lib, har xil sharoitda o‘sa oladi. Do‘lananing ayrim turlari yashil to‘siq uchun juda mos keladi. Ularni butash va shakl berish oson. Bular qatoriga Oddiy tikanli do‘lana (Crataegus oxyacantha L.) turlarini kiritish mumkin. Do‘lana mazali mevasi bilan mashxur. Uning ko‘p turlari Xitoyda, Italiyada, Jazoirda, Ispaniyada, Meksikada va Gvatemalada mevasi uchun ekiladi. Uning yetilgan mevasi yumshoq, shirin va nordon bo‘ladi. Undan marmelad, qiyom va kisel tayyorlashda foydalaniladi.

3-rasm. Do'lananing gullash jarayonini kuzatish

4-rasm. Do'lananing barg chiqarish fazasini kuzatish

Do'lana mevasining mazasi, shakli, rangi, hajmi, tashqi ko'rinishiga qarab har xil bo'ladi. Crataegus pseudoazarolus L., Crataegus pontica C.Koch., Crataegus submollis Sarg., turlari mevalarining yirikligi bilan diqqatga sazovordir.

Kimyoviy tarkibi. Ushbu do'lana mevalarining tarkibida 20% qand, 8% yog', flavonoidlar, fitosterinlar, xolin, asetilxolin, oshlovchi moddalar, vitamin S, organik moddalar mavjud. O'zbekiston sharoitida o'sadigan do'lananing ba'zi turlarida vitamin V1, V2, RR, S, Ye borligi aniqlangan. O'simlik gullarida yuqorida qayd qilingan moddalardan tashqari 0,16 % ga yaqin efir moylari bor.

O'zbekistonda do'lanadan ko'p foydalanish mumkin, jumladan, Crataegus pontica C.Koch. juda mos keladi, chunki uning ildiz sistemasi yuzada bo'lib, yon tomonga qarab o'sadi va tuproqning yuvilishidan saqlaydi. Do'lananing gullari nektarli, u turli vaqtda gullashi tufayli gullari yil bo'yi asalarilar uchun oziq manbai bo'ladi. Mevasidan ekstrakt tayyorlanadi. Barg va gullarini qaynatib suvi ichilsa markaziy asab tuzulishini tinchlanishiga ta'sir etadi. Meva ekstrakti yurak faoliyatini yaxshilashda va qon bosimini pasaytirishda yaxshi samara beradi. Ushbu foydali o'simlikni tog'larda plantatsiya usulida yetishtirish, mevalarning oziqaviylik va dorivorlik xususiyatlaridan keng foydalanish kerak.

Do'lanadan payvantag sifatida foydalanish mumkin, unga olma, nok, bexi, ulanadi. Do'lana ildizidan, urug'idan, ildiz bachkisi va ildiz poyasidan parxish yuli bilan xam ko'paytiriladi. Do'lana idanagining qobig'i juda qattiq, ekilgandan keyin 2 yoki 3 chi yili unib chiqadi. Agar uni sulfat kislotaga 12 soat solinib, birinchi yildanoq unib chiqadi.

XULOSA

Do'lana sovuqqa qurg'oqchilikka chidamli, undan o'rmon melioratsiya ishlarida foydalanish mumkin. Jumladan, sariq do'lana G.pontika juda mos keladi, chunki uning yon ildiz sistemasi asosan yuzada bo'lib, 2-3 m chuqurligi esa 1,5-2 m gacha borib

yetadi. Tuproqni yuvilishidan, eroziyaga qarshi tog‘ bag‘irlarini mustaxkamlashda va yashil devor, ihota daraxtzorlari xosil qilishda foydalanish uchun tavsiya qilinadi.

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ACHCHIQ QALAMPIRNI AGROBIOLOGIK HUSUSIYATLARINI O‘RGANISH VA QURITISHGA MOS NAVLARINI TANLASH.

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Annotatsiya: *Ushbu ilmiy maqolada achchiq qalampirning (Capsicum annuum L.) agrobiologik xususiyatlari o‘rganildi va quritishga mos navlarni tanlash bo‘yicha tahlillar qilindi. Tadqiqot jarayonida achchiq qalampirning, hosildorligi, meva morfologiyasi, kimyoviy tarkibi (quruq modda, kapsaitsin miqdori) hamda ekologik omillarga moslashuv darajasi baholandi. Shuningdek, turli navlarning quritish jarayonidagi sifat ko‘rsatkichlari, jumladan rang saqlanishi, ta’m xususiyatlari va texnologik qulayligi o‘rganildi. Tadqiqot natijalari achchiq qalampir yetishtirish va qayta ishlash samaradorligini oshirish, shuningdek, eksportbop mahsulotlar ishlab chiqarishda quritilgan qalampirning muhim ahamiyatlari haqidagi ma’lumotlar keltilgan.*

Kalit so‘zlar: *achchiq qalampir, agrobiologik xususiyatlar, Capsicum annuum, nav tanlash, quritish texnologiyasi, quruq modda, kapsaitsin, hosildorlik, biologik pishish, organaleptik.*

Аннотация: *В данной научной статье изучены агробиологические особенности острого перца (Capsicum annuum L.) и проведён анализ по подбору сортов, пригодных для сушки. В процессе исследования оценивались урожайность острого перца, морфология плодов, химический состав (содержание сухого вещества, капсаицина), а также степень адаптации к экологическим факторам. Также изучены качественные показатели различных сортов в процессе сушки, включая сохранность цвета, вкусовые характеристики и технологическую пригодность. Результаты исследования содержат данные о повышении эффективности выращивания и переработки острого перца, а также о важности сушёного перца для производства экспортоориентированной продукции.*

Ключевые слова: *острый перец, агробиологические особенности, Capsicum annuum, подбор сортов, технология сушки, сухое вещество, капсаицин, урожайность, биологическое созревание, органолептика.*

Abstract: *This scientific article examines the agrobiological characteristics of hot pepper (Capsicum annuum L.) and provides an analysis of selecting varieties suitable for drying. During the research, the yield, fruit morphology, chemical composition (dry matter and capsaicin content), as well as the adaptability to environmental factors of hot pepper were assessed. Additionally, the quality indicators of various varieties during the drying process, including color retention, taste characteristics, and technological suitability, were studied. The research findings*

present data on improving the efficiency of hot pepper cultivation and processing, as well as the significance of dried pepper in producing export-oriented products.

Keywords: *hot pepper, agrobiological characteristics, Capsicum annuum, variety selection, drying technology, dry matter, capsaicin, yield, biological maturity, organoleptic.*

KIRISH

Bugungi kunda achchiq qalampir dunyo bo‘yicha 4,6 mln gektar maydonga ekilib, undan 69,3 mln tonna mahsulot yetishtirilmoqda. O‘rtacha hosildorlik issiqxonalarda gektaridan 100-110 tonnani, ochiq maydonlarda esa 14,1-18,3 tonnani tashkil etmoqda. Hozirgi kunda achchiq qalampir ekiniga qiziqish va ehtiyoj kundan-kunga ortib bormoqda, bu ekin dunyoning barcha mamlakatlarida yetishtiriladi. Achchiq qalampirni dunyo miqyosida o‘rtacha hosildorlik ko‘rsatkichi ochiq maydonlarda 2006-yilda 7,3 tonnadan, 2019-yilda 18,4 tonnagacha ko‘tarilgan bo‘lsa, issiqxonalarda 80 tonnadan 110 tonnagacha ko‘tarilgan.

Mamlakatimizda muhim tarmoq – qishloq xo‘jaligini isloh qilish, xususan sohada davlat boshqaruvi tizimini takomillashtirish, bozor munosabatlarini keng joriy qilish, qishloq xo‘jaligi mahsulotlarini yetishtiruvchi, qayta ishlovchi va sotuvchi subyektlar o‘rtasidagi munosabatlarning huquqiy asosini mustahkamlash, sohaga investitsiyalarni jalb qilish, resurstejamkor texnologiyalarni joriy etish hamda qishloq xo‘jaligi mahsulotlari ishlab chiqaruvchilarni zamonaviy texnikalar bilan ta’minlash borasida muayyan ishlar amalga oshirilmoqda.

TADQIQOTNING USULLARI

Achchiq qalampirni quritishda Z.S.Iskandarov [Kombinirovonnaya solnechno-toplivnaya ustanovka] tavsiya etgan uslubdan foydalanilgan va tayyor mahsulot sifatini baholash esa ГОСТ 29053-91 [Pryanosti. Peres krasnыy molotiy. Texnicheskie usloviya. – Moskva: IPK Izdatelstvo standartov] talablari asosida amalga oshirilgan. “Mahsulot sifatini baholash” Shirokov Ye.P Organolepticheskie metodi osenok pishevix produktov Y.P.Shirokov va V.I.Polegayevlarning uslubi bo‘yicha tahlil etilgan.

TAJRIBA NATIJALARI

Tajribilarimizda dastlab o‘rganilayotgan achchiq qalampirning nav va duragaylarini yetishtirish sharoitiga bog‘liq bo‘lgan jihatlari o‘rganilib vegetatsiya davomiyligida fenologik kuzatuvlar olib borildi. Tadqiqotlar shuni ko‘rsatdiki achchiq qalampirning nav va duragaylari ko‘chatlari ochiq maydonga ekilgandan so‘ng dastlabki gullash va mevalarni yetilish ko‘rsatkichlari nav va duragaylar aro turlicha ko‘rsatkichda bo‘lganligi aniqlandi.

Qalampir o‘simligi tomatdoshlar *(Solanaceae)* oilasiga mansub bo‘lib, asosan madaniy holda (*Sapsicum annuum* L.) turi ko‘p maydonlarga ekib parvarishlanadi. O‘simlikning yer ustki qismi, poyasi o‘tsimon, tik o‘sadi, bo‘yi 25-30 sm dan 80 sm gacha, shoxlanuvchan ko‘rinishda bo‘ladi. Barglari bandli, usti silliq yoki tukli, uzunchoq shaklda bo‘lib, yirik va enli bo‘ladi. Gullari ikki jinsli, mayda oq, sariq yoki

och binafsha rangda bo‘lib, 9 ta tojbargi bor. Urug‘dan ekilgandan so‘ng 80-90 kun o‘tgach, iyun-iyul oyida gullaydi va gullash kuzgi sovuq tushguncha davom etadi. Mevalari shakliga qarab 14 turdagi mevalarga ajratiladi: sharsimon, ovalsimon, tuxumsimon, yassi-yumaloq, prizmasimon, konussimon, xartumsimon, silindrsimon. Tajribalarimizda o‘rganilayotgan achchiq qalampirning nav va duragaylarining mevalari asosan konussimon va qisman prizmasimon shaklga ega. Achchiq qalampir mevalarining turli ko‘rsatkichlari nav va duragaylar aro turlicha bo‘lib, meva uzunligi 2-20 sm, diametri 4-10 sm, meva devorining qalinligi 2-8 mm, mevasining rangi texnik yetilganda och, to‘q ko‘k, biologik yetilganda esa sariqdan to‘q qizilgacha, meva vazni o‘rtacha 25 g dan 45g gacha bo‘lishi tajribalarimiz davomida aniqlandi (1-jadval).

1-jadval

Achchiq qalampirni o‘simligining nav va duragaylarini vegetatsiya davomiyligi, hosildorlik ko‘rsatkichlari va mevasining morfologik va morfometrik ko‘rsatkichlari (2023-2025 y.y)

№	Achchiq qalampir navlari	Vegeta-siya davomiy-ligi, kun	Biologik pishib yetilganda mevasi-ning rangi	Bir dona meva-ning vazni,gr	Hosildor-ligi, t/ga	Degusta-sion bahosi, ball
1	Marg‘ilon 330	120-125	qizil	19-20	14-18	4,4
2	Pikantniy	120-123	qizil	20-21	11-12	4,3
3	Said	118-122	yashil-qizil	35-38	22-24	4,5
4	Mumtoz	135-140	qizil	10-12	45-50	4,4

Tajribalarimiz davomida achchiq qalampiri o‘simligining nav va duragaylarini turli agrobiologik va xo‘jalik belgilari tahlil etildi. Aytish joizki achchiq qalampir mevalarini quritishga tayyorlash davomimda nav va duragaylarni bir qancha agrobiologik xususiyatlari, xo‘jalik belgilari va mevasining morfologik va morfometrik ko‘rsatkichlari nav va duragaylar aro taqqoslab chiqildi.

Tajribalarimizda o‘rganilayotgan achchiq qalampirning nav va duragaylarini agrobiologik xususiyatlarini o‘rganishdan maqsad ularni quritishga mos xususiyalarini o‘rganishga qaratilgan. Dastlabki tajribalarimizda achchiq qalampir o‘simligining nav va duragaylarini vegetatsiya davomiyligi, meva rangi, meva vazni, hosildorlik ko‘rsatkichlari va degustatsion bahosi tahlil etildi. Bunda achchiq qalampirning “Marg‘ilon 330” navining ushbu ko‘rsatkichlari o‘rganilganda, vegetatsiya davri 120-125 kun, biologik pishib yetilganda mevasining rangi qizil, bir dona mevasining vazin ko‘rsatkichi o‘rtacha 19-20 gr, hosildorlik ko‘rsatkichi 14-18 t/ga va degustatsion bahosi 4,4 ballni tashkil etganligi aniqlandi.

Ushbu ko‘rsatkichlar achchiq qalampirning “Pikantniy” navida tahlil etilganda vegetatsiya davri 120-123 kun, biologik pishib yetilganda mevasining rangi qizil, bir dona mevasining vazin ko‘rsatkichi o‘rtacha 20-21 gr, hosildorlik ko‘rsatkichi 11-12 t/ga va degustatsion bahosi 4,3 ballni tashkil etdi.

Achchiq qalampirning “Said” navida ushbu qo‘rsatkich quyidagicha bo‘laganligi kuzatildi. Bunda vegetatsiya davri 118-122 kun, biologik pishib yetilganda mevasining rangi qizil, bir dona mevasining vazin ko‘rsatkichi o‘rtacha 35-38 gr, hosildorlik ko‘rsatkichi 22-24 t/ga va degustatsion bahosi 4,5 ballni tashkil etdi. Achchiq qalampirning “Mumtoz” navida ushbu ko‘rsatkich quyidagicha bo‘laganligi kuzatildi. Bunda vegetatsiya davri 135-140 kun, biologik pishib yetilganda mevasining rangi qizil, bir dona mevasining vazin ko‘rsatkichi o‘rtacha 10-12 gr, hosildorlik ko‘rsatkichi 45-50 t/ga va degustatsion bahosi 4,4 ballni tashkil etganligi tashribalarimizda aniqlandi.

Ushbu tajribada achchiq qalampirning nav va duragaylarini yuqorida qayd etilgan ko‘rsatkichlari tahlil etilganda barcha ko‘rsatkichlarda, turli nav va duragaylarda bir biridan farqlanish darajalari turlicha ko‘rsatkichlarda bo‘lganligi aniqlandi. Achchiq qalampirining navlari ochiq maydonda parvarishlanganda issiqxonada parvarishlangan achchiq qalampirining duragaylariga taqqoslanganda vegetatsiya davomiyligi 10-20 kunga farqlanishi ya’ni issiqxonada parvarishlangan qalampir o‘simliklari ochiq maydonda parvarishlangan qalampir o‘simliklariga nisbatan 10-20 kun kam vaqt oralig‘ida bo‘lganligi aniqlandi.

Achchiq qalampirning barcha nav va duragaylarining mevalarini vazin ko‘rsatkichlari taqqoslanganda issiqxonada parvarishlangan duragaylarning mevalari 40-60 gr yuqori ko‘rsatkichda bo‘lganligi aniqlandi. Eng yuqori ko‘rsatkich achchiq qalampirining “Pikantniy”, “Said” duragaylarida eng yuqori ko‘rsatkichda bo‘lganligi kuzatildi.

Ushbu achchiq qalampirning nav va duragaylarining hosildorlik ko‘rsatkichlari tahlil etilganda “Said” va “Mumtoz” navlarida yuqori ko‘rsatkichda bo‘lganligi aniqlandi. Ushbu tajribada achchiq qalampirning nav va duragaylari mevalarining degustatsion bahosi “Said” duragayida 4,5 ball, “Mumtoz” 4,4 ball eng yuqori ko‘rsatkich qayd etildi. Bashqa nav va duragaylarda esa 4-4,3 ball ko‘rsatkichda bo‘lganligi aniqlandi (1-rasm).

1-rasm Achchiq qalampirning navlari mevalarini morfologik, morfometrik ko‘rsatkichlarini tahlil etish hamda degustatsion baholash jarayoni

Tadqiqotlar davomida achchiq qalampir nav va duragaylarining mevalari turli ko‘rsatkichlari, morfologik va morfometrik belgilari o‘rganilganda nav va duragaylar aro turlicha farqlanishlar aniqlandi.

XULOSA

Olib borilgan tadqiqotlar natijasida achchiq qalampirning agrobiologik xususiyatlari uning nav xususiyatlariga va etishtirish sharoitlariga bevosita bog‘liqligi aniqlandi. Quritishga mos navlarni tanlashda mevaning quruq modda miqdori, etining qalinligi, rang va kapsaitsin miqdori asosiy mezonlar sifatida belgilandi. Tajribalarimiz davomida achchiq qalampirining nav va duragaylari, tarkibidagi namlik miqdori va quruq modda miqdori laboratoriya sharoitida tahlil etildi, har bir achchiq qalampir nav va duragaylari mevalaridan 20 donadan namunalar tanlab olinib mevaning bo‘yi, eni, meva eti qalanligi, meva tarkibidagi suv miqdori va meva tarkibidagi quruq modda miqdori laboratoriya sharoitida aniqlandi. Umuman olganda, mazkur tadqiqot natijalari achchiq qalampirni samarali yetishtirish, qayta ishlash va eksport salohiyatini oshirishda ilmiy-amaliy asos bo‘lib xizmat qiladi.

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QAND LAVLAGI O‘SIMLIGI KIMYOVIY TARKIBI, XUSUSIYATLARI VA MINERAL O‘G‘ITLARNING AHAMIYATI

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Annotatsiya. *Ushbu maqolada qand lavlagi (Beta vulgaris L. var. saccharifera) o‘simligining kimyoviy tarkibi, agrobiologik xususiyatlari hamda mineral o‘g‘itlarning hosildorlik va texnologik sifatga ta’siri IMRAD talablari asosida yoritildi. Qand lavlagi ildizi sanoat uchun muhim xomashyo bo‘lib, uning asosiy qiymati ildizda to‘planadigan sacharoza miqdori, quruq modda ulushi, suv rejimi va qayta ishlashga ta’sir qiluvchi no-shakar birikmalar bilan belgilanadi. Adabiyotlar tahlili shuni ko‘rsatadiki, texnik pishgan qand lavlagi ildizida odatda 75-85% suv, 15-22% gacha sacharoza va turli mineral hamda organik no-shakar moddalar mavjud bo‘ladi. Mineral oziqlanishda azot vegetativ massa va ildiz hosilini shakllantirsa, fosfor ildiz tizimi hamda energiya almashinuvini kuchaytiradi, kaliy esa uglevodlar translokatsiyasi, suv rejimi va sanoat shakar chiqimida muhim rol o‘ynaydi. Biroq azotning kech yoki ortiqcha berilishi shakar foizini kamaytirishi va melassa hosil bo‘lishini kuchaytirishi mumkin. Maqolada qand lavlagi kimyoviy tarkibi, NPK va mikroelementlarning fiziologik vazifalari, mineral o‘g‘itlar bilan tajriba modeli, sifat ko‘rsatkichlari jadvali hamda diagrammalar keltirildi. Tahlil natijalariga ko‘ra, qand lavlagida yuqori ildiz hosili va yuqori shakar miqdorini bir vaqtda ta’minlash uchun mineral oziqlanish tuproq tahlili, nav xususiyati, namlik rejimi va o‘simlik rivojlanish bosqichlariga moslashtirilgan holda olib borilishi zarur.*

Kalit so‘zlar: *qand lavlagi, Beta vulgaris, kimyoviy tarkib, sacharoza, mineral oziqlanish, azot, fosfor, kaliy, bor, hosildorlik, shakar miqdori.*

Аннотация. *В статье на основе структуры IMRAD рассмотрены химический состав сахарной свёклы (Beta vulgaris L. var. saccharifera), её агробиологические особенности и значение минеральных удобрений для формирования урожайности и технологического качества корнеплодов. Сахарная свёкла является важным сырьём для сахарной промышленности, а её ценность определяется содержанием сахарозы, сухого вещества, водным режимом и уровнем несахаристых веществ, влияющих на переработку. По данным литературы, зрелые корнеплоды обычно содержат 75-85% воды и до 15-22% сахарозы, а также органические и минеральные соединения. Азот способствует формированию листовой массы и урожая корнеплодов, фосфор улучшает развитие корневой системы и энергетический обмен, а калий играет ключевую роль в транспорте углеводов, водном балансе и выходе белого сахара. Однако избыточное или позднее внесение азота может снижать сахаристость и ухудшать технологическое качество. В статье представлены таблицы, схемы и диаграммы, отражающие химический состав растения, роль макро- и*

микроэлементов, модель опыта с минеральными удобрениями и рекомендуемую систему питания сахарной свёклы.

Ключевые слова: *сахарная свёкла, Beta vulgaris, химический состав, сахароза, минеральное питание, азот, фосфор, калий, бор, урожайность, сахаристость.*

Abstract. *This article presents an IMRAD-based analysis of the chemical composition, agronomic characteristics, and role of mineral fertilizers in sugar beet (Beta vulgaris L. var. saccharifera) production. Sugar beet is an important industrial crop, and its value is determined mainly by sucrose accumulation in the storage root, dry matter content, water status, and non-sugar compounds affecting processing quality. Literature data indicate that technically mature sugar beet roots generally contain about 75-85% water and up to 15-22% sucrose, together with different organic and mineral non-sugar compounds. Nitrogen supports canopy development and root yield formation, phosphorus contributes to root system development and energy metabolism, while potassium is essential for carbohydrate translocation, water regulation, and industrial sugar yield. However, excessive or late nitrogen application may reduce sucrose concentration and deteriorate processing quality. The article includes tables, a technological scheme, and diagrams summarizing sugar beet composition, physiological functions of macro- and micronutrients, a mineral fertilizer experiment model, and recommended nutrient management approaches. The analysis suggests that balanced fertilization based on soil testing, cultivar characteristics, moisture regime, and crop development stage is essential to achieve high root yield and high sugar content simultaneously.*

Keywords*: sugar beet, Beta vulgaris, chemical composition, sucrose, mineral nutrition, nitrogen, phosphorus, potassium, boron, yield, sugar content.*

1. KIRISH

Qand lavlagi (Beta vulgaris L. var. saccharifera) dunyoda shakar ishlab chiqarishda muhim o‘rin tutadigan texnik ekinlardan biridir. U ikki yillik biologik siklga ega bo‘lsa-da, shakar olish maqsadida odatda birinchi vegetatsiya yilining oxirida, ya’ni ildizda maksimal miqdorda sacharoza to‘plangan davrda yig‘ib olinadi. Qand lavlagining sanoat ahamiyati uning ildizida to‘planadigan sacharoza, ildiz hosili, quruq modda, kul elementlari, azotli birikmalar va qayta ishlash jarayoniga ta’sir qiluvchi no-shakar moddalarning nisbati bilan belgilanadi.

FAO ma’lumotlarida qand lavlagi Beta vulgaris turiga mansub ekin sifatida tavsiflanadi va u shakar ishlab chiqarish uchun yetishtiriladigan asosiy ekinlardan biri ekani ko‘rsatiladi. Qand lavlagining afzalligi shundaki, u nisbatan salqin iqlim sharoitida o‘sib, shakarqamish yetishtirish qiyin bo‘lgan hududlarda sanoat shakar xomashyosi sifatida foydalaniladi. O‘simlikning asosiy fotosintez mahsulotlari barglarda hosil bo‘ladi va vegetatsiya oxirida ildizga ko‘chib, sacharoza ko‘rinishida zaxiralanadi.

Qand lavlagi ildizining kimyoviy tarkibi o‘simlikning nav xususiyati, tuproq unumdorligi, harorat, suv bilan ta’minlanish, kasalliklar, yig‘im-terim muddati va mineral oziqlanishga bog‘liq. Ildizdagi shakar miqdori yuqori bo‘lishi uchun o‘simlik

dastlab kuchli barg apparatini shakllantirishi, keyin esa vegetativ o‘sishni sekinlashtirib, fotosintez mahsulotlarini ildizga yo‘naltirishi kerak. Shu sababli mineral o‘g‘itlarning vazifasi faqat hosildorlikni oshirish emas, balki hosilning texnologik sifatini ham boshqarishdan iborat.

Azot, fosfor va kaliy qand lavlagi oziqlanishida eng muhim makroelementlar hisoblanadi. Azot barg massasi, xlorofill va oqsil sintezi uchun zarur. Fosfor energiya almashinuvi, ildiz tizimi rivojlanishi va erta o‘sish jarayonlarida muhim rol o‘ynaydi. Kaliy esa uglevodlar sintezi va ularning barglardan ildizga ko‘chishini ta’minlashda, suv rejimini boshqarishda hamda sanoat shakar chiqimini yaxshilashda bevosita ishtirok etadi. Bor, magniy, oltingugurt, rux va marganes kabi elementlar esa fermentativ jarayonlar, hujayra devori shakllanishi, fotosintez va stressga chidamlilikda muhim ahamiyatga ega.

Mavzuning dolzarbligi shundaki, amaliy dehqonchilikda mineral o‘g‘itlar ko‘pincha faqat hosildorlikni oshirish vositasi sifatida qaraladi. Ammo qand lavlagida ortiqcha azot yoki noto‘g‘ri muddatda berilgan oziqa elementlari ildiz massasini oshirgan holda shakar foizini pasaytirishi mumkin. Shuning uchun qand lavlagi uchun mineral oziqlanish tizimi hosildorlik, shakar miqdori, quruq modda, qayta ishlash sifati va ekologik xavfsizlik ko‘rsatkichlarini birgalikda hisobga olgan holda baholanishi kerak.

Ushbu maqolaning maqsadi qand lavlagi o‘simligining kimyoviy tarkibi va asosiy biologik xususiyatlarini yoritish, mineral o‘g‘itlarning fiziologik va agrotexnologik ahamiyatini tahlil qilish hamda qand lavlagi yetishtirishda muvozanatli oziqlanish tizimini ilmiy asoslashdan iborat.

2. MATERIALLAR VA METODLAR

Maqola tahliliy-uslubiy xarakterga ega bo‘lib, unda qand lavlagi kimyoviy tarkibi, mineral oziqlanishi va o‘g‘itlarning hosildorlik hamda sifat ko‘rsatkichlariga ta’siri bo‘yicha ilmiy manbalar umumlashtirildi. Asosiy ma’lumotlar agronomiya, o‘simlik fiziologiyasi, oziqlanish va qand lavlagi yetishtirish texnologiyasi bo‘yicha chop etilgan monografiyalar, ilmiy maqolalar hamda xalqaro ma’lumot bazalari asosida shakllantirildi.

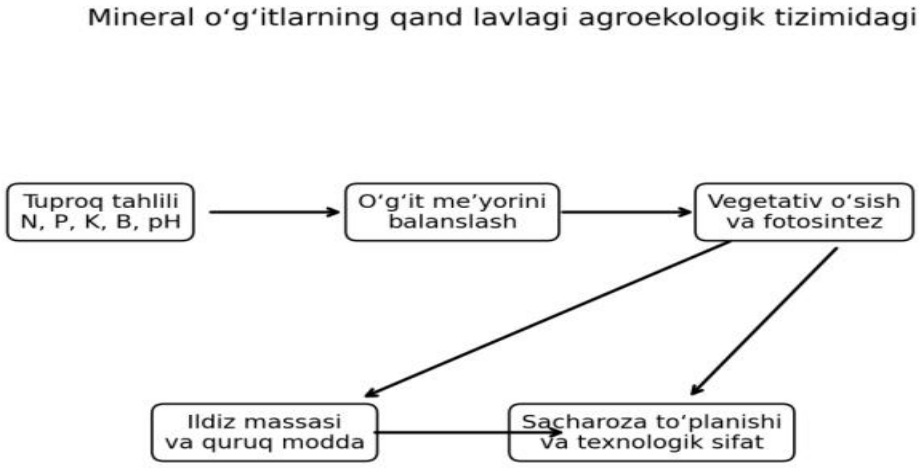
Tahlilda uchta yo‘nalish ajratildi: birinchisi, qand lavlagi ildizining kimyoviy tarkibini tavsiflash; ikkinchisi, o‘simlikning agrobiologik xususiyatlarini ochib berish; uchinchisi, mineral o‘g‘itlarning hosil va texnologik sifatga ta’sir mexanizmini baholash. Shuningdek, dala tajribasi uchun qo‘llanishi mumkin bo‘lgan namunaviy tajriba sxemasi ishlab chiqildi.

Tajriba modelida mineral o‘g‘itlar ta’sirini o‘rganish uchun nazorat varianti, azot-fosfor-kaliy kombinatsiyalari va mikroelementli variantlar kiritildi. Bu model real dala tajribasi o‘tkazilganda tuproq sharoiti, nav, sug‘orish rejimi va ekish zichligiga moslab o‘zgartirilishi mumkin. Natijalar qismida berilgan diagrammalar adabiyotlarda qayd etilgan umumiy qonuniyatlar asosida tuzilgan model ko‘rsatkichlar bo‘lib, ular ilmiy tajriba loyihasini tushuntirish maqsadida keltirildi.

Baholash mezonlari sifatida ildiz hosildorligi, ildizdagi sacharoza miqdori, quruq modda, kul moddalar, azotli no-shakar birikmalar, qayta ishlash sifati, oq shakar

chiqimi va o‘simlikning oziqa elementlariga javob reaksiyasi tanlandi. Mineral elementlarning fiziologik roli esa o‘simlik oziqlanishi nazariyasi, fotosintez, uglevodlar translokatsiyasi va ildizda zaxira moddalar to‘planishi nuqtayi nazaridan izohlandi.

Rasm 1. Mineral o‘g‘itlarning qand lavlagi agroekologik tizimidagi ta’sir zanjiri

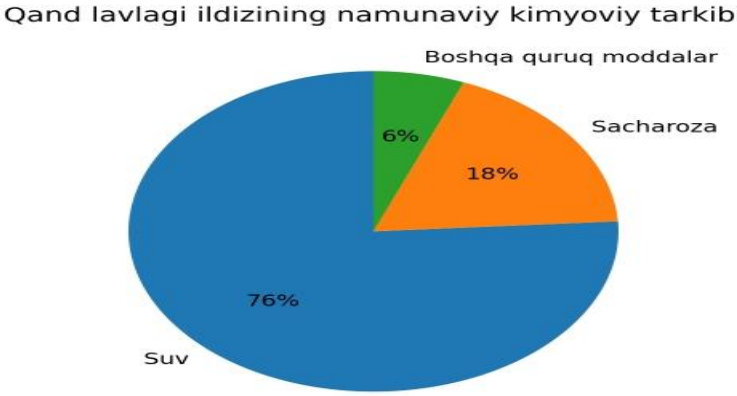


3. NATIJALAR

3.1. Qand lavlagi ildizining kimyoviy tarkibi. Qand lavlagi ildizining asosiy komponenti suv hisoblanadi. Texnik pishgan ildizlarda suv miqdori odatda 75-85% atrofida bo‘ladi. Quruq moddaning asosiy qismini sacharoza tashkil etadi. Adabiyotlarda qand lavlagi ildizida sacharoza miqdori ko‘pincha 15-20%, ayrim sharoitlarda 21-22% gacha yetishi mumkinligi ko‘rsatiladi. Sacharozadan tashqari ildiz tarkibida pektin, sellyuloza, gemitsellyuloza, betain, aminokislotalar, mineral tuzlar, organik kislotalar va boshqa no-shakar moddalar uchraydi.

Qayta ishlash sanoati uchun faqat ildizdagi umumiy shakar foizi emas, balki oq shakar chiqimini kamaytiruvchi komponentlar ham muhimdir. Ayniqsa natriy, kaliy va alfa-amino azot miqdori yuqori bo‘lsa, melassa hosil bo‘lishi ortadi va zavodda olinadigan kristall shakar ulushi kamayishi mumkin. Demak, qand lavlagining kimyoviy tarkibi dehqonchilik texnologiyasining bevosita natijasi sifatida baholanishi kerak.

Diagramma 1. Qand lavlagi ildizining namunaviy kimyoviy tarkibi



Jadval 1. Qand lavlagi ildizining asosiy kimyoviy komponentlari

Komponent	Odatdagi diapazon	Fiziologik yoki texnologik ahamiyati
Suv	75-85%	Hujayra turgori, metabolizm, massa va saqlash barqarorligini belgilaydi.
Sacharoza	15-22% gacha	Asosiy sanoat mahsuloti; oq shakar chiqimini belgilovchi bosh ko‘rsatkich.
Quruq modda	20-25% atrofida	Sacharoza, pektin, tolalar, mineral moddalar va organik birikmalar yig‘indisi.
Kletchatka va pektinlar	3-6% atrofida	Ildiz tuzilishi va lavlagi pulpasining ozuqaviy qiymatini belgilaydi.
Azotli no-shakar moddalar	nav va oziqlanishga bog‘liq	Qayta ishlashda melassa hosil bo‘lishini kuchaytirishi mumkin.
Kul elementlari	0,5-1,0% atrofida	K, Na, Ca, Mg, P va mikroelementlarni o‘z ichiga oladi.
Betain va organik kislotalar	kam miqdorda	Osmotik muvozanat, stressga javob va qayta ishlash xususiyatlariga ta’sir qiladi.

3.2. Qand lavlagi o‘simligining asosiy agrobiologik xususiyatlari. Qand lavlagi ikki yillik o‘simlik bo‘lib, birinchi yilda kuchli barg rozetkasi va zaxira moddalarga boy ildiz hosil qiladi. Ikkinchi yilda esa generativ rivojlanish boshlanadi va gul poyasi shakllanadi. Shakar ishlab chiqarishda o‘simlik birinchi yil yakunida yig‘ib olinadi, chunki bu davrda ildizda sacharoza to‘planishi eng yuqori darajaga yaqinlashadi.

Qand lavlagi fotosintez mahsulotlarini samarali zaxiralashi bilan ajralib turadi. Barg apparati dastlab ildiz massasini shakllantirish uchun xizmat qiladi. Vegetatsiya oxirida barglarning haddan tashqari kuchli o‘sishi foydali emas, chunki u fotosintez mahsulotlarining ildizda sacharoza sifatida to‘planishini cheklashi mumkin. Shuning uchun o‘sishning erta davrida oziqa elementlari yetarli, pishish davrida esa azot me’yori nazorat ostida bo‘lishi zarur.

Qand lavlagi chuqur ildiz tizimiga ega bo‘lib, unumdor, yaxshi ishlangan, o‘rtacha og‘ir mexanik tarkibli va pH 6,5-7,5 atrofidagi tuproqlarda yaxshi o‘sadi. Kuchli sho‘rlanish, tuproq zichlanishi, namlik yetishmasligi, yuqori harorat va kasalliklar ildiz shakli, hosildorlik va shakar miqdorini pasaytiradi. Shu bilan birga, lavlagi ayrim bosqichlardan keyin nisbatan sho‘r va qurg‘oqchil sharoitlarga moslasha oladigan ekin hisoblanadi.

Jadval 2. Qand lavlagining agrobiologik xususiyatlari

Xususiyat	Tavsifi	Amaliy ahamiyati
Biologik sikl	Ikki yillik, lekin shakar uchun birinchi yilda yig‘iladi.	Yig‘im-terim muddati sacharoza maksimal to‘plangan davrga mos tanlanadi.
Fotosintez apparati	Keng barg yuzasi hosil qiladi.	Dastlab yuqori vegetativ o‘sish, keyin sacharoza to‘planishi zarur.
Ildiz tizimi	Chuqur o‘suvchi asosiy ildiz va yon ildizlar.	Tuproq zichlanishi ildiz deformatsiyasi va hosil kamayishiga olib keladi.
Iqlim talabi	Salqin va mo‘tadil iqlimga mos.	Vegetatsiya oxiridagi salqin kechalar shakar to‘planishiga qulay.
Tuproq talabi	Unumdor, yaxshi drenajlangan, o‘rtacha og‘ir tuproq.	pH juda past yoki tuproq qobiq hosil qilsa, nihol siyraklashadi.
Sanoat ko‘rsatkichi	Sacharoza, oq shakar chiqimi, alfa-amino azot, K va Na.	Faqat ildiz massasini emas, qayta ishlash sifatini ham baholash kerak.

3.3. Mineral elementlarning fiziologik vazifalari. Qand lavlagi yuqori biomassa va ildiz hosili shakllantiruvchi ekin bo‘lgani sababli mineral oziqa elementlariga talabi yuqori. Oziqa elementlari orasida azot, fosfor va kaliy asosiy o‘rinda turadi. Ular bir-birini almashtira olmaydi, shuning uchun har bir element alohida fiziologik funksiyaga ega bo‘lishi bilan birga, o‘zaro muvozanatda qo‘llanganda eng yuqori natija beradi.

Azot yetishmaganda barglar och yashil tusga kiradi, o‘sish sekinlashadi va ildiz massasi kamayadi. Ammo ortiqcha azot vegetativ massani haddan tashqari kuchaytirib, ildizdagi sacharoza foizini kamaytirishi, alfa-amino azot miqdorini oshirishi va qayta ishlash sifatini pasaytirishi mumkin. Fosfor yetishmovchiligida erta ildizlanish sustlashadi, energiya almashinuvi pasayadi va o‘simlik sovuq hamda stressga sezgir bo‘lib qoladi. Kaliy esa qand lavlagida eng muhim sifat elementlaridan biri hisoblanadi, chunki u fotosintez mahsulotlari harakati, suv rejimi, fermentlar faolligi va stressga chidamlilikni qo‘llab-quvvatlaydi.

Mikroelementlardan bor qand lavlagi uchun ayniqsa muhim. Bor yetishmovchiligi o‘sish nuqtasining zararlanishi, ildizning ichki chirishi, barg deformatsiyasi va shakar miqdorining pasayishi bilan namoyon bo‘lishi mumkin. Rux, marganes, mis, temir va molibden fermentativ reaksiyalar, fotosintez, azot almashinuvi va oksidlanish-qaytarilish jarayonlarida ishtirok etadi.

Jadval 3. Mineral elementlarning qand lavlagidagi fiziologik vazifalari

Element	Asosiy vazifasi	Yetishmovchilik oqibati	Ortiqcha yoki noto‘g‘ri qo‘llash xavfi
Azot (N)	Barg massasi, xlorofill, oqsil va ildiz hosilini shakllantiradi.	Barglar och yashil, o‘sish sust, hosil past.	Kech yoki ortiqcha berilsa shakar foizi kamayadi, no-shakar azot ortadi.
Fosfor (P)	Energiya almashinuvi, ildiz tizimi, erta rivojlanish.	Ildizlanish sust, o‘sish sekin, stressga chidamlilik past.	Ko‘p berilganda ayrim mikroelementlar o‘zlashtirilishi cheklanishi mumkin.
Kaliy (K)	Uglevodlar transporti, suv rejimi, fermentlar faolligi.	Barg chetlari qurishi, qurg‘oqchilikka sezgirlik, sifat pasayishi.	Tuproqdagi Mg va Ca muvozanatiga ta’sir qilishi mumkin.
Bor (B)	Hujayra devori, o‘sish nuqtasi, shakar tashilishi.	Yurak chirishi, ildiz deformatsiyasi, sifat pasayishi.	Me’yoridan ortiq bo‘lsa toksiklik xavfi bor.
Magniy (Mg)	Xlorofill markaziy atomi, fotosintez.	Barglarda xloroz, assimilatsiya pasayishi.	Kaliy bilan antagonizm paydo bo‘lishi mumkin.
Oltingugurt (S)	Aminokislotalar va oqsillar sintezi.	O‘sish sustlashadi, yosh barglar sarg‘ayadi.	Ortiqcha sulfat sho‘rlanishga hissa qo‘shishi mumkin.

3.4. Mineral o‘g‘itlar bilan tajriba modeli. Qand lavlagida mineral o‘g‘itlar ta’sirini to‘g‘ri baholash uchun tajriba oddiy NPK qo‘llash bilan cheklanmasligi kerak. Chunki hosildorlik va shakar miqdori bir-biriga har doim ham bir yo‘nalishda javob bermaydi. Masalan, azot me’yori oshganda ildiz massasi ortishi mumkin, lekin juda yuqori azot shakar foizini pasaytirishi mumkin. Shuning uchun tajribada ildiz

hosildorligi, shakar foizi, oq shakar hosili va no-shakar moddalar birgalikda baholanishi zarur.

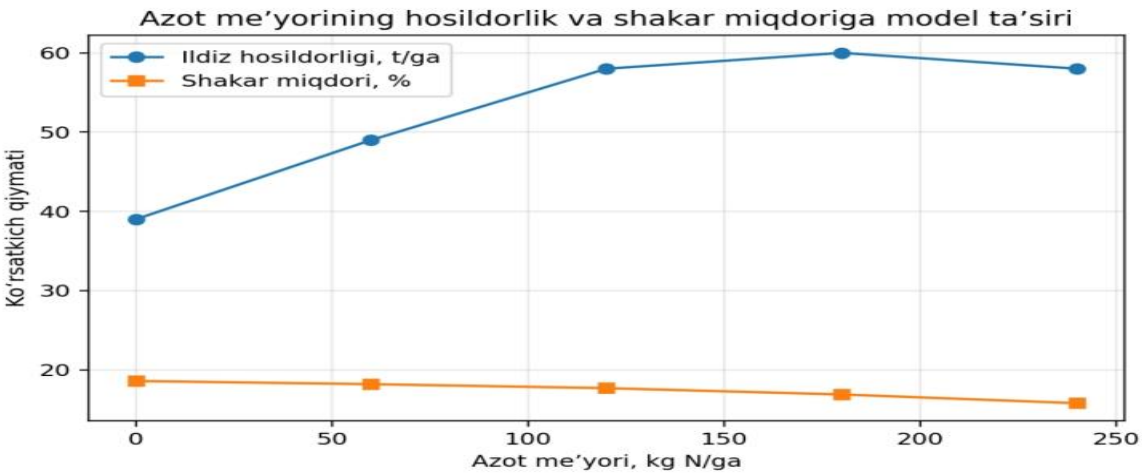
Jadval 4. Qand lavlagida mineral o‘g‘itlar bo‘yicha namunaviy tajriba sxemasi

Variant	Mineral oziqlanish sxemasi	Tajribaning maqsadi
T0	O‘g‘itsiz nazorat	Tuproqning tabiiy unumdorligi va bazaviy hosilni aniqlash.
T1	N90P60K90	O‘rtacha NPK fonining hosil va sifatga ta’sirini aniqlash.
T2	N120P60K120	Yuqori ildiz hosili uchun muvozanatli NPK me’yorini baholash.
T3	N150P60K120	Azot oshirilganda ildiz massasi va shakar foizi o‘zgarishini aniqlash.
T4	N120P90K120	Fosforning ildizlanish va erta rivojlanishdagi rolini baholash.
T5	N120P60K180	Kaliyning uglevodlar translokatsiyasi va oq shakar chiqimiga ta’sirini baholash.
T6	N120P60K120 + B	Borning o‘sish nuqtasi, ildiz sifati va shakar to‘planishidagi rolini tekshirish.
T7	N120P60K120 + B + Mg + Zn	Makro- va mikroelementlar kompleksining texnologik sifatga ta’sirini baholash.

3.5. Azot me’yorining hosildorlik va shakar miqdoriga ta’siri. Azot qand lavlagi hosildorligini oshirishda eng kuchli omillardan biri hisoblanadi. Yetarli azot barg massasining tez rivojlanishini, fotosintez yuzasining kengayishini va ildiz hosilining shakllanishini qo‘llab-quvvatlaydi. Biroq azotning kech berilishi yoki yuqori me’yorlarda qo‘llanishi o‘simlikda vegetativ o‘sishni uzoq davom ettirib, ildizda sacharoza to‘planishini cheklashi mumkin.

Diagramma 2 da adabiyotlarda qayd etilgan umumiy qonuniyat asosida tuzilgan model ko‘rsatilgan. Unga ko‘ra, azot me’yori 0 dan 120-180 kg/ga gacha oshganda ildiz hosildorligi ortadi. Ammo 180-240 kg/ga darajasida shakar foizi pasayishi kuzatiladi. Demak, azotning maqbul me’yori faqat maksimal ildiz massasi bilan emas, balki oq shakar hosili va qayta ishlash sifati bilan belgilanadi.

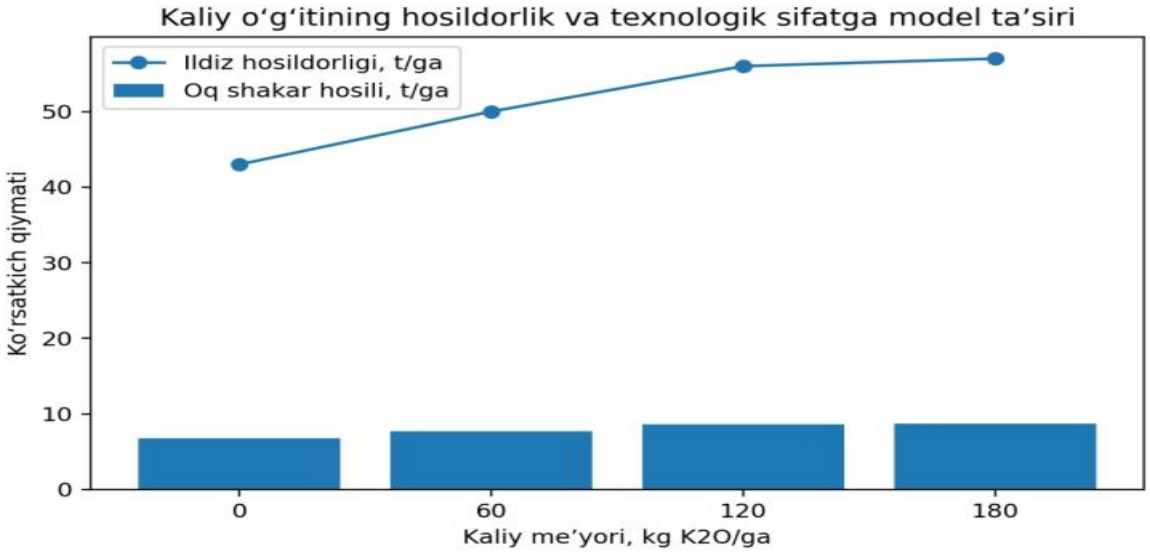
Diagramma 2. Azot me’yorining hosildorlik va shakar miqdoriga model ta’siri



3.6. Fosfor va kaliyning hosil sifatidagi o‘rni. Fosfor qand lavlagining erta rivojlanish bosqichida ayniqsa muhimdir. Nihollar ildiz tizimini tez shakllantirsa, keyingi davrlarda suv va oziqa elementlarini yaxshiroq o‘zlashtiradi. Fosfor yetishmovchiligi sovuq bahor sharoitida kuchliroq seziladi, chunki past harorat tuproqda fosfor harakatchanligini cheklaydi. Shuning uchun fosforli o‘g‘itlarni ekishdan oldin yoki ekish bilan birga ildiz zonasiga yaqin berish samarali bo‘lishi mumkin.

Kaliy qand lavlagida sacharoza to‘planishi bilan bevosita bog‘liq bo‘lgan elementlardan biri sifatida baholanadi. U barglarda hosil bo‘lgan uglevodlarning ildizga ko‘chishini, hujayra osmotik bosimini, suvdan foydalanish samaradorligini va stressga chidamlilikni yaxshilaydi. Kaliy yetarli bo‘lgan sharoitda ildiz massasining ortishi bilan birga sanoat shakar chiqimi ham yaxshilanishi mumkin. Shu sababli qand lavlagi yetishtirishda K2O me’yori tuproqdagi almashinuvchan kaliy miqdori va rejalashtirilgan hosil darajasiga qarab belgilanadi.

Diagramma 3. Kaliy o‘g‘itining hosildorlik va texnologik sifatga model ta’siri



3.7. Tavsiya etiladigan mineral oziqlanish tizimi. Qand lavlagida mineral o‘g‘itlarni qo‘llashda asosiy tamoyil - o‘simlik rivojlanish bosqichlariga mos oziqlantirishdir. Ekish oldidan tuproq tahlili asosida fosfor va kaliyning asosiy qismi beriladi. Azot esa ko‘pincha bo‘lib beriladi: bir qismi ekish oldidan, qolgan qismi esa erta vegetatsiya davrida. Vegetatsiyaning kech bosqichida azot berishdan saqlanish zarur, chunki bu shakar to‘planishini pasaytirishi mumkin.

Jadval 5. Qand lavlagi uchun bosqichma-bosqich mineral oziqlanish tizimi

Bosqich	Oziqlantirish vazifasi	Tavsiya etiladigan yondashuv
Ekishdan oldin	Tuproq zaxirasini baholash va bazaviy oziqa fondini yaratish.	Tuproq tahlili, pH nazorati, P va K ning asosiy qismini berish.
Nihollash va 4-6 barg	Ildizlanish va barg apparatini tez shakllantirish.	Azotning birinchi qismi, zarur bo‘lsa fosforning start doza shakli.
Faol vegetativ o‘sish	Fotosintez yuzasi va ildiz massasi hosil bo‘lishi.	Azotning asosiy qismi, kaliy bilan muvozanatlash, sug‘orish nazorati.

Bosqich	Oziqlantirish vazifasi	Tavsiya etiladigan yondashuv
Ildiz kattalashishi	Uglevodlar ildizga ko‘chishi va quruq modda ortishi.	Kaliy, magniy va bor ta’minotini nazorat qilish.
Pishish davri	Sacharoza maksimal to‘planishi va qayta ishlash sifatini saqlash.	Kech azotdan saqlanish, ortiqcha sug‘orishni cheklash, kasallik nazorati.

4. MUHOKAMA

Qand lavlagi yetishtirishda asosiy muammo hosildorlik va shakar miqdori o‘rtasidagi muvozanatni topishdan iborat. Ildiz massasi yuqori bo‘lgani bilan shakar foizi past bo‘lsa, sanoat uchun foydali mahsulot miqdori kutilgan darajada bo‘lmasligi mumkin. Aksincha, shakar foizi yuqori, lekin ildiz hosili past bo‘lsa ham oq shakar hosili kamayadi. Shuning uchun qand lavlagi samaradorligini baholashda ildiz hosildorligi, shakar foizi va oq shakar chiqimi birgalikda qo‘llanishi kerak.

Azotli o‘g‘itlar eng ehtiyotkorlik bilan boshqarilishi kerak bo‘lgan mineral oziqa guruhiga kiradi. Erta davrda yetarli azot o‘simlikka kuchli barg apparatini shakllantirishga yordam beradi. Lekin pishish davriga yaqin azotning yuqori bo‘lishi vegetativ o‘sishni davom ettiradi va sacharoza to‘planishini sekinlashtiradi. Shu sababli amaliyotda azotni bo‘lib berish, tuproqdagi mineral azotni tahlil qilish va o‘g‘itni ekin ehtiyojiga moslashtirish muhim.

Fosforning ahamiyati ko‘pincha hosildorlikka bevosita ta’sir bilan emas, balki erta rivojlanishni barqarorlashtirish bilan namoyon bo‘ladi. Yaxshi ildizlangan nihol keyinchalik suv va oziqa elementlarini samarali o‘zlashtiradi. Bu ayniqsa bahorda tuproq harorati past bo‘lgan hududlarda muhimdir. Shuning uchun fosforli o‘g‘itlarni yuzaki emas, ildiz zonasiga yaqin joylashtirish samarali bo‘lishi mumkin.

Kaliy qand lavlagi sifatini shakllantiruvchi asosiy elementlardan biridir. U barglardan ildizga uglevodlar ko‘chishini rag‘batlantiradi, hujayra shirasining osmotik bosimini boshqaradi va suv tanqisligi sharoitida o‘simlikning bardoshini oshiradi. Kaliy o‘g‘itlari, ayniqsa namlik yetishmasligi yoki yengil tuproq sharoitida, ildiz hosili va shakar chiqimiga ijobiy ta’sir ko‘rsatishi mumkin.

Bor yetishmovchiligi qand lavlagida keskin sifat muammolarini keltirib chiqaradi. Bu element hujayra devori shakllanishi, o‘sish nuqtasi faoliyati va uglevodlar transportida ishtirok etgani uchun uning yetishmovchiligi ildizning ichki chirishi, barg deformatsiyasi va hosilning pasayishiga olib keladi. Biroq borning foydali va toksik me’yorlari orasidagi farq nisbatan kichik bo‘lgani uchun uni qo‘llashda tuproq va barg tahliliga asoslanish zarur.

Mineral o‘g‘itlardan foydalanishda ekologik jihat ham e’tibordan chetda qolmasligi kerak. Azotning ortiqcha qo‘llanishi nitratlarning yuvilishi, issiqxona gazlari chiqishi va ishlab chiqarish xarajatlarining ortishiga olib kelishi mumkin. Shuning uchun qand lavlagi yetishtirishda 4R tamoyili - to‘g‘ri o‘g‘it turi, to‘g‘ri me’yor, to‘g‘ri muddat va to‘g‘ri joylashtirish - asosiy boshqaruv yondashuvi bo‘lishi kerak.

5. XULOSA

1. Qand lavlagi ildizi kimyoviy jihatdan suv, sacharoza, quruq modda, tolalar, pektinlar, azotli birikmalar, kul elementlari va boshqa no-shakar moddalardan tashkil

topadi. Sanoat uchun eng muhim ko‘rsatkichlar ildiz hosildorligi, sacharoza foizi, oq shakar chiqimi va qayta ishlashga xalaqit beruvchi no-shakar moddalar miqdoridir.

2. O‘simlikning biologik xususiyati shundan iboratki, dastlab barg apparati va ildiz massasi shakllanadi, vegetatsiya oxirida esa fotosintez mahsulotlari ildizga ko‘chib, sacharoza sifatida zaxiralanadi. Shu sababli mineral oziqlanish tizimi o‘sish bosqichlariga mos ravishda boshqarilishi kerak.

3. Azot qand lavlagi hosildorligini oshiradi, lekin ortiqcha yoki kech qo‘llanganda shakar foizini pasaytirishi mumkin. Fosfor erta ildizlanish va energiya almashinuvini qo‘llab-quvvatlaydi. Kaliy uglevodlar transporti, suv rejimi va sanoat shakar chiqimi uchun muhim. Bor esa o‘sish nuqtasi, hujayra devori va ildiz sifatini saqlashda alohida ahamiyatga ega.

4. Qand lavlagida mineral o‘g‘itlarning maqbul tizimi tuproq tahlili, nav xususiyati, rejalashtirilgan hosil, sug‘orish rejimi va mahalliy iqlim sharoitlariga asoslanishi kerak. Eng to‘g‘ri yondashuv hosildorlikni oshirish bilan birga shakar miqdori va qayta ishlash sifatini saqlashga qaratilgan muvozanatli oziqlanishdir.

5. Kelgusida qand lavlagi bo‘yicha ilmiy tadqiqotlarda NPK me’yorlari bilan bir qatorda bor, magniy, rux va boshqa mikroelementlarning ta’sirini, shuningdek, o‘g‘itlardan foydalanish samaradorligi va ekologik xavfsizlik ko‘rsatkichlarini kompleks baholash maqsadga muvofiq.

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SANOAT HUDUDLARI SHAROITIDA HIMOYA O‘RMON EKINZORLARINI BARPO ETISHNING AGROTEXNIK ASOSLARINI ISHLAB CHIQISH

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Annotatsiya. *Sanoat hududlari atrofida himoya o‘rmon ekinzorlarini barpo etishda daraxt turlarini to‘g‘ri tanlash muhim agrotexnik masaladir. Chirchiq shahridagi “Maxam-Chirchiq” zavodi atrofida o‘sadigan to‘rt xil daraxt turining og‘ir metallarni akkumulyatsiya qilish qobiliyati ISP-MS usulida baholandi va shu asosda tur tanlash reytingi tuzildi. Eman va gozal katalpaning yuqori akkumulyatsiya salohiyati ularni himoya o‘rmon polosalarining tashqi (“filtr”) qatorida ekish uchun eng maqbul tur sifatida tavsiya etish imkonini berdi. Olingan natijalar asosida ko‘p qatorli himoya polosasi tarkibini shakllantirish, ekish va parvarish qilish bo‘yicha aniq agrotexnik tavsiyalar ishlab chiqildi.*

Kalit so‘zlar: *himoya o‘rmon ekinzori, agrotexnika, tur tanlash, og‘ir metallar, sanoat hududi, shamol to‘sig‘i, ko‘kalamzorlashtirish.*

Аннотация. *Правильный подбор древесных пород является важной агротехнической задачей при создании защитных лесных полос вокруг промышленных зон. Методом ИСП-МС была оценена способность четырех видов деревьев, произрастающих вблизи завода «Максам-Чирчик» в городе Чирчик, накапливать тяжелые металлы, на основе чего составлен рейтинг подбора пород. Высокий аккумулятивный потенциал дуба и катальпы позволил рекомендовать их для посадки во внешнем («фильтрующем») ряду защитной полосы. На основе полученных результатов разработаны конкретные агротехнические рекомендации по формированию состава многорядной защитной полосы, посадке и уходу за насаждениями.*

Ключевые слова: *защитная лесная полоса, агротехника, подбор пород, тяжелые металлы, промышленная зона, ветрозащита, озеленение.*

Abstract. *Proper selection of tree species is a critical agrotechnical task in establishing protective forest shelterbelts around industrial zones. Using ICP-MS, this study assessed the heavy metal accumulation capacity of four tree species growing near the “Maxam-Chirchiq” plant in Chirchiq city and developed a species-selection ranking. The high accumulation potential of oak and catalpa supported their recommendation for planting in the outer (“filter”) row of the shelterbelt. Based on*

the results, concrete agrotechnical recommendations were developed for forming the composition of a multi-row shelterbelt, planting, and maintenance.

Keywords: *protective shelterbelt, agrotechnics, species selection, heavy metals, industrial zone, windbreak, greening.*

KIRISH

Sanoat korxonalari atrofida barpo etiladigan himoya o‘rmon ekinzorlari (shelterbelt) atmosfera ifloslanishini kamaytirish, shamol va chang tarqalishining oldini olish hamda qo‘shni qishloq xo‘jaligi yerlarini himoya qilishda muhim vazifani bajaradi. Jahon amaliyotida bunday himoya polosalari faqat mikroiqlimni yaxshilash vositasi sifatida emas, balki tuproq eroziyasini kamaytiruvchi, uglerodni sekvestrlash va biologik xilma-xillikni saqlashga xizmat qiluvchi kompleks agroekologik infratuzilma sifatida qaraladi.

Tarixiy jihatdan himoya o‘rmon polosalari dunyoning ko‘plab mamlakatlarida keng qo‘llanilgan: Xitoyning “Uch Shimol” davlat dasturi (Three-North Shelter Forest Program) 1978-yildan boshlab dunyodagi eng yirik sun'iy o‘rmonzorlashtirish loyihasi hisoblanadi, Kanadaning Prairie Shelterbelt dasturi 1903-yildan buyon 600 milliondan ortiq ko‘chat yetkazib bergan. Markaziy Osiyo mintaqasida ham daraxt qatorlari dala chegaralari va sug‘orish kanallari bo‘ylab an'anaviy shamol to‘sig‘i vazifasini bajarib kelgan, biroq sovet davridan keyingi davrda yoqilg‘i tanqisligi sababli ko‘plab himoya polosalari kesib tashlangan, bu esa hozirgi kunda ularni tiklash va ilmiy asoslangan tarzda qayta barpo etish zaruriyatini keltirib chiqarmoqda.

Sanoat korxonalari atrofidagi himoya polosalari oddiy shamol to‘sig‘idan farqli o‘laroq, qo‘shimcha vazifani ham bajaradi — ular havodagi va tuproqdagi og‘ir metallarni o‘zida ushlab qolib, atrofdagi qishloq xo‘jaligi yerlari va aholi punktlarini ifloslanishdan himoya qiladi. Shu sababli, bunday sharoitda daraxt turini tanlash oddiy shamoldan himoyalanish mezonlaridan tashqari, uning ifloslantiruvchi moddalarni akkumulyatsiya qilish qobiliyatini ham hisobga olishi lozim.

ADABIYOTLAR TAHLILI

Enescu va hammualliflarining keng qamrovli bibliometrik tahlilida 1984–2024 yillar oralig‘ida himoya o‘rmon polosalari va qishloq xo‘jaligiga oid 762 ta ilmiy nashr tahlil qilingan bo‘lib, ular himoya polosalarining tuproq eroziyasini 80% gacha kamaytirishi, shamol tezligini 30–50% ga pasaytirishi hamda uglerod sekvestratsiyasini sezilarli darajada oshirishi mumkinligini ko‘rsatgan. Xususan, himoya polosasi tuprog‘ida organik uglerod miqdori qo‘shni dala tuprog‘iga nisbatan 27% ga yuqori bo‘lgani qayd etilgan.

Smith va hammualliflari AQShda o‘tkazilgan tizimli sharhida fermerlarning himoya polosalariga nisbatan qarashlarini o‘rgangan bo‘lib, ko‘plab fermerlar ularning foydasini tan olsa-da, yer maydonining kamayishi va uzoq muddatli iqtisodiy noaniqlik sabab ularni joriy etishdan tortinishini aniqladi. Rempel va hammualliflari Kanadaning Saskachevan provinsiyasida o‘tkazilgan tadqiqotida ishlab chiqaruvchilarning himoya polosalari xarajatlari va foydasi haqidagi tasavvurlarini tahlil qilib, iqtisodiy asoslash yetishmasligi joriy etishning asosiy to‘sig‘i ekanligini ko‘rsatdi. Baker va hammualliflari esa shamol to‘sig‘ining ekin va chorva mahsuldorligiga ta'sirini

o‘rganib, shamol tezligining 50% gacha kamayishi yosh chorva mollarining omon qolish darajasi va oziqlanish samaradorligini sezilarli oshirishini aniqladi.

Enescu va hammualliflarining tadqiqotida shuningdek ta'kidlanishicha, himoya polosasi tarkibiga kiritiladigan daraxt turini tanlashda uning tez o‘sishi, zich shoxlanishi, shamol, quyosh va sovuqqa chidamliligi kabi omillar hisobga olinishi kerak, biroq sanoat zonalarida esa bunga qo‘shimcha ravishda turning havodagi ifloslantiruvchi moddalarni (chang, og‘ir metallar) qanchalik samarali ushlab qolish qobiliyati ham asosiy mezon bo‘lishi lozim. Bu jihat mavjud xalqaro adabiyotlarda alohida chuqur o‘rganilmagan bo‘lib, ko‘pchilik tadqiqotlar shamoldan himoyalanish va tuproq eroziyasi masalalariga qaratilgan, ifloslantiruvchi moddalarni akkumulyatsiya qilish qobiliyatiga asoslangan tur tanlash mezoni esa alohida metodologik yondashuv sifatida deyarli ishlab chiqilmagan.

Enescu va hammualliflarining bibliometrik tahlilida shuningdek qayd etilishicha, himoya polosalarining iqtisodiy jihatdan maqbul konstruksiyasi ularning balandligi, kengligi va g‘ovakligi (porosity) bilan belgilanadi: o‘rtacha g‘ovaklik (40–60%) shamol tezligini eng samarali kamaytiradi, keragidan ortiq zich polosalar esa aksincha turbulentlik hosil qilib, salbiy ta'sir ko‘rsatishi mumkin. Bir qatorli himoya polosalari odatda iqtisodiy jihatdan neytral yoki biroz foydali bo‘lsa, ko‘p qatorli polosalar aniq moliyaviy hisob-kitobni talab qiladi — tadqiqotlarga ko‘ra, polosa balandligining 13 baravariga teng oraliqda joylashtirilgan himoya polosalari makkajo‘xori va soya kabi ekinlar uchun eng yuqori iqtisodiy samara beradi.

Tadqiqotning maqsadi — sanoat zonasida keng tarqalgan to‘rt xil daraxt turining og‘ir metallarni akkumulyatsiya qilish qobiliyatini aniqlash va shu asosda himoya o‘rmon ekinzorini barpo etish, tur tanlash, ekish va parvarish qilish bo‘yicha agrotexnik tavsiyalar ishlab chiqishdan iborat.

TADQIQOT METODOLOGIYASI

Tadqiqot obyekti sifatida Chirchiq shahridagi "Maksam-Chirchiq" zavodi atrofida o‘sadigan to‘rt xil manzarali daraxt turi — eman (Quercus), sharq chinori (Platanus orientalis), gozal katalpa (Catalpa) va soxta kashtan (Aesculus) — bargidan iyul oyida olingan namunalar xizmat qildi.

Namunalar tarkibidagi og‘ir metallar (Pb, Zn, Cu, Ni, Cd, Mn, Sr, Ba, Co, As) miqdori induktiv bog‘langan plazma mass-spektrometriyasi (ISP-MS, NEXION-2000 asbobi) usulida aniqlandi. Namunalar 0,0500–0,5000 g miqdorda analitik tarozida o‘lchanib, teflon avtoklavlarda konsentrlangan azot kislotasi va vodorod peroksidi bilan Berghof mikroto‘lqinli parchalagichida (MWS-3+ dasturi) parchalandi va 0,5% li azot kislotasi bilan 50–100 ml hajmga keltirildi.

Olingan kimyoviy tahlil natijalari asosida har bir turning umumiy akkumulyatsiya darajasi bo‘yicha tavsiflovchi reyting tuzildi (1-jadval). Bu reyting agrotexnik tahlilning boshlang‘ich nuqtasi sifatida xizmat qildi: reytingda yuqori o‘rin olgan turlar himoya polosasining ifloslanishga eng ko‘p duch keladigan tashqi qatoriga, past o‘rin olganlar esa ichki qatorlarga tavsiya etildi. Agrotexnik parametrlar (qatorlar oralig‘i, ekish chuqurligi, parvarish muddatlari) xalqaro amaliyotda qabul qilingan umumiy shelterbelt loyihalash normalari asosida belgilandi.

Agrotexnik tavsiyalarni ishlab chiqishda uchta asosiy mezon qo‘llanildi: (1) turning ifloslantiruvchi moddalarni akkumulyatsiya qilish qobiliyati — ISP-MS tahlili natijalariga asoslangan; (2) turning agrobiologik xususiyatlari — o‘sish tezligi, toj kengligi, tuproq va suv rejimiga chidamliligi — mavjud dendrologik ma'lumotnomalar asosida baholangan; (3) turning shahar/sanoat landshaftidagi amaliy va estetik ahamiyati. Ushbu uch mezon birgalikda har bir turning himoya polosasidagi optimal o‘rnini belgilashga xizmat qildi.

TAHLIL VA NATIJALAR

To‘rt xil daraxt turining og‘ir metallarni akkumulyatsiya qilish qobiliyatini baholash natijasida olingan ma’lumotlar asosida tur tanlash reytingi hamda himoya o‘rmon polosasining tavsiya etilgan qatorlar tarkibi shakllantirildi. Quyida ushbu natijalar jadvallar ko‘rinishida keltirilib, ularning agrotexnik ahamiyati muhokama etiladi.

1-jadval.

Tur tanlash reytingi: akkumulyatsiya darajasi va himoya polosasidagi tavsiya etilgan o‘rin

O‘rin	Daraxt turi	Akkumulyatsiya darajasi	Tavsiya etilgan joylashuv
1	Eman (Quercus)	Yuqori (Pb, Zn, Ni, Cd bo‘yicha yetakchi)	Tashqi ("filtr") qator — zavodga eng yaqin
2	Gozal katalpa (Catalpa)	Yuqori (Sr, As bo‘yicha yetakchi)	Tashqi ("filtr") qator
3	Soxta kashtan (Aesculus)	O‘rtacha (Mn, Ba bo‘yicha yuqori)	O‘rta qator
4	Sharq chinori (P. orientalis)	Past (aksariyat elementlarda eng kam)	Ichki qator / xiyobon

1-jadvalda keltirilgan reyting og‘ir metallarni akkumulyatsiya qilish qobiliyati (ISP-MS tahlili natijalari) asosida tuzildi. Natijalarga ko‘ra, eman va gozal katalpa eng yuqori akkumulyatsiya ko‘rsatkichlariga ega bo‘lib, ularni himoya o‘rmon polosasining zavodga yaqin, birinchi ("filtr") qatoriga ekish tavsiya etiladi. Sharq chinori va soxta kashtan esa nisbatan past akkumulyatsiya ko‘rsatkichiga ega bo‘lib, ular polosaning ichki qatorlarida yoki xiyobon sifatida qo‘llanilishi maqsadga muvofiqdir. Bunday farqlangan yondashuv chekli maydonda maksimal himoya samaradorligiga erishish imkonini beradi.

Himoya polosasining agrotexnik tarkibi. Tavsiya etilayotgan ko‘p qatorli himoya o‘rmon polosasi tarkibi va qatorlar oralig‘i 2-jadvalda keltirilgan.

2-jadval.

Himoya o‘rmon polosasining tavsiya etilgan qatorlar tarkibi

Qator №	Vazifasi	Tavsiya etilgan tur	Qatorlar orasi, m
1 (zavodga yaqin)	Ifloslantiruvchi moddalarni ushlab qolish ("filtr")	Eman, Gozal katalpa	2,5–3,0
2–3 (o‘rta)	Qo‘shimcha himoya, shamoldan to‘sish	Soxta kashtan, Sharq chinori	2,5–3,0

Qator №	Vazifasi	Tavsiya etilgan tur	Qatorlar orasi, m
4 (ichki, dala tomon)	Estetik, mikroiqlim yaxshilash	Sharq chinori / xiyobon turlari	3,0

Bunday tuzilma Enescu va hammualliflari tomonidan ta'kidlangan umumiy tamoyilga mos keladi: eng samarali himoya polosalari bir necha qatordan iborat bo‘lib, aralash turlardan tashkil topgan polosalar bir turli polosalarga nisbatan yuqori himoya samaradorligiga ega. Qatorlar orasidagi masofa (2,5–3,0 m) daraxtlarning yetarli yorug‘lik va oziq maydoni olishini ta'minlaydi, bu esa ularning to‘liq rivojlanishi va uzoq muddatli himoya funksiyasini bajarishi uchun zarur shart hisoblanadi. Bu xulosa Aili va hammualliflarining arid mintaqalar uchun ishlab chiqilgan ko‘p maqsadli optimallashtirish modeli bilan ham tasdiqlanadi — ularning tadqiqotiga ko‘ra, o‘rtacha g‘ovaklik (30–50%) va ko‘p qatorli, aralash turlardan tashkil topgan tuzilma shamol tezligini eng samarali kamaytiradi hamda hosildorlikni 10–25% ga oshirishi mumkin.

Shimoliy-Sharqiy Xitoyning qora tuproqli mintaqasida o‘tkazilgan tadqiqotlarda ham turli daraxt turlaridan tashkil topgan himoya polosalari tuproq fizik-kimyoviy xususiyatlari va mikrob hamjamiyati tarkibiga sezilarli ta'sir ko‘rsatishi, xususan aralash turlardan iborat polosalar yakka turli polosalarga nisbatan tuproq unumdorligi va suv ushlab turish qobiliyatini yaxshiroq ta'minlashi aniqlangan. Bu natijalar taklif etilayotgan to‘rt turli aralash himoya polosasining nafaqat havo, balki tuproq sifatiga ham ijobiy ta'sir ko‘rsatishi mumkinligini ko‘rsatadi.

Shuni alohida qayd etish lozimki, taklif etilgan sxemada eman va gozal katalpaning tashqi qatorga joylashtirilishi faqat ularning yuqori akkumulyatsiya qobiliyatiga emas, balki agrobiologik xususiyatlariga ham asoslangan: har ikkala tur ham nisbatan tez o‘sadigan, keng tojga ega va turli tuproq sharoitlariga chidamli hisoblanadi, bu ularni eng ko‘p ekologik stressga duch keladigan tashqi qatorda o‘stirish uchun maqbul qiladi. Sharq chinori va soxta kashtanning ichkariroq qatorlarga joylashtirilishi esa ularning nisbatan past akkumulyatsiya ko‘rsatkichi bilan bir qatorda, ularning baland bo‘yli va estetik jihatdan qimmatli turlar ekanligini ham hisobga oladi, bu turlar polosaning ichki, kamroq ifloslangan qismida ko‘proq dekorativ va rekreatsion vazifani bajarishi mumkin.

Tuproqqa ishlov berish va ekish tartibi. Ko‘chatlarni ekishdan oldin tuproq 40–50 sm chuqurlikda haydalib, organik o‘g‘itlar (chirigan go‘ng yoki kompost) qo‘shilishi tavsiya etiladi. Ko‘chatlar ko‘klam yoki kuz mavsumida, tuproq namligi yetarli bo‘lgan davrda ekiladi. Birinchi 2–3 yil davomida muntazam sug‘orish va begona o‘tlardan tozalash zarur, bu davrda ildiz tizimining shakllanishi va daraxtning tashqi muhitga moslashuvi ta'minlanadi. Bu davr Smith va hammualliflari tomonidan ham himoya polosalarining eng zaif, ya'ni asosiy parvarish talab qiladigan bosqichi sifatida ta’riflangan.

Ekish zichligi va sxemasini belgilashda daraxt turining kattalashgandagi toj diametri hisobga olinishi zarur: eman va gozal katalpa kabi keng tojli turlar uchun kattaroq oraliq (3,0 m atrofida), nisbatan ixcham tojga ega turlar uchun esa 2,0–2,5 m oraliq yetarli bo‘lishi mumkin. Ekish chuqurligi ko‘chat ildiz tizimi hajmidan 1,5–2 baravar katta bo‘lishi, ekish chuqurchasi tubiga drenaj qatlami (mayda shag‘al yoki qum) joylashtirilishi tavsiya etiladi — bu, ayniqsa og‘ir, sizot suvlari yuqori tuproqlarda, ildiz chirishining oldini oladi.

Zamonaviy monitoring texnologiyalari. So‘nggi yillarda GIS, pilotsiz uchar apparatlar (UAV) va masofaviy zondlash texnologiyalari himoya polosalarini loyihalash va monitoring qilish samaradorligini sezilarli oshirmoqda. Bunday texnologiyalar orqali daraxt turlarini avtomatik aniqlash, polosaning zichligi va uzluksizligini masofadan baholash, shuningdek vaqt o‘tishi bilan o‘sish dinamikasini kuzatish mumkin. Kelgusida O‘zbekiston sharoitida ham bunday zamonaviy vositalardan foydalanish himoya o‘rmon polosalarining holatini muntazam va arzon narxda monitoring qilish imkonini beradi, bu esa an'anaviy dala tekshiruvlariga qaraganda ancha samarali va operativ yondashuv hisoblanadi.

Parvarish va monitoring. Himoya polosasi barpo etilgandan so‘ng, undagi daraxtlar barglarida to‘plangan og‘ir metallar miqdorini har 2–3 yilda bir marta tahlil qilib turish tavsiya etiladi. Bu, birinchidan, polosaning ifloslantiruvchi moddalarni ushlab qolish samaradorligini nazorat qilish, ikkinchidan, ma'lum vaqtdan so‘ng barglar va tuproqda to‘plangan elementlarning ikkilamchi ifloslanish manbaiga aylanib qolmasligini oldini olish imkonini beradi. Yiqilgan barglarni maxsus yig‘ib utilizatsiya qilish, ayniqsa yuqori akkumulyativ turlar (eman, gozal katalpa) uchun tavsiya etiladi.
Biologik xilma-xillikka ta’siri. Enescu va hammualliflarining tahliliga ko‘ra, himoya o‘rmon polosalari nafaqat ifloslanishga qarshi kurashda, balki qishloq xo‘jaligi landshaftlarida biologik xilma-xillikni saqlashda ham muhim rol o‘ynaydi — ular parazit hasharotlar, chumolilar va changlatuvchi hasharotlar uchun tabiiy yashash muhiti (ekologik dahliz) vazifasini bajaradi, bu esa kimyoviy pestitsidlarga bo‘lgan ehtiyojni kamaytirishga yordam beradi. Aralash turlardan tashkil topgan himoya polosalari, bir turli polosalarga nisbatan, xilma-xil hasharotlar populyatsiyasini qo‘llab-quvvatlashda yanada samarali ekanligi ko‘rsatilgan. Shu nuqtai nazardan, taklif etilayotgan to‘rt turli (eman, sharq chinori, gozal katalpa, soxta kashtan) himoya polosasi tarkibi nafaqat og‘ir metallarni akkumulyatsiya qilish, balki ekologik xilma-xillikni ta'minlash nuqtai nazaridan ham maqsadga muvofiqdir.

Iqtisodiy va ekologik samaradorlik**.** Enescu va hammualliflarining bibliometrik tahliliga ko‘ra, himoya polosalarining tashqi (jamoat) foydasi, xususan uglerod sekvestratsiyasi va tuproq eroziyasining kamayishi hisobiga, sezilarli iqtisodiy qiymatga ega bo‘lib, bu qiymat ko‘plab hollarda million dollarlik miqyosda baholanadi. Rempel va hammualliflari ta'kidlaganidek, himoya polosalarining boshlang‘ich xarajatlari (ko‘chat, ekish, dastlabki parvarish) bir martalik bo‘lsa-da, ularning uzoq muddatli foydasi — ifloslanishni kamaytirish, tuproq eroziyasining oldini olish va qo‘shni ekin maydonlari hosildorligini saqlab qolish — ancha yuqori baholanadi. Shuningdek, tegishli davlat dasturlari (o‘rmon fondini kengaytirish, ko‘kalamzorlashtirish) doirasida bunday himoya polosalarini barpo etish uchun subsidiya yoki grant dasturlaridan foydalanish imkoniyati ham mavjud.
Baker va hammualliflarining tadqiqotida qayd etilishicha, shamol to‘sig‘i ta'siridagi “tinch zona” (quiet zone) — bu polosa balandligining 3–10 baravariga teng masofa — ichida ekin hosildorligi sezilarli oshadi: masalan, bug‘doy va suli hosili Avstraliyaning Rutherglen shahrida 22% ga, Esperance shahrida esa loviya (lupin) hosili 30% ga ko‘tarilgani qayd etilgan. Bu ma'lumotlar shuni ko‘rsatadiki, himoya polosasi tomonidan egallangan yer maydonining yo‘qotilishi, odatda, qo‘shni ekin

maydonlaridagi hosildorlik oshishi hisobiga to‘liq qoplanadi va hatto undan oshib ketadi. Sanoat zonalari sharoitida esa bu foyda yana bir bosqich — havo va tuproq ifloslanishining kamayishi — bilan to‘ldiriladi, bu esa qo‘shni ekin maydonlarida yetishtiriladigan mahsulotning ekologik xavfsizligini oshiradi.

Mahalliy sharoitga moslashtirish zarurati. Shuni alohida ta'kidlash lozimki, xalqaro adabiyotlarda keltirilgan agrotexnik parametrlarning aksariyati mo'tadil iqlim mintaqalari (Shimoliy Amerika, Markaziy Yevropa) sharoitida ishlab chiqilgan. O‘zbekistonning issiq va quruq kontinental iqlimi, yuqori bug‘lanish darajasi va sug‘orma dehqonchilik an'analari sharoitida bu parametrlarni to‘g‘ridan-to‘g‘ri qo‘llash o‘rniga, ularni mahalliy tuproq-iqlim sharoitlariga moslashtirish, xususan sug‘orish rejimi va qator oralig‘ini mahalliy suv ta'minoti imkoniyatlariga muvofiqlashtirish zarur.

Xususan, yozgi issiq davrda (июнь–август) havo harorati +35–40 °C ga yetadigan mintaqalarda ko‘chatlarning dastlabki 2–3 yillik davrida sug‘orish oralig‘i standart mo'tadil iqlim tavsiyalariga (10–14 kun) nisbatan qisqartirilishi, issiq kunlarda esa tomchilatib sug‘orish tizimini qo‘llash suv resurslaridan tejamkor foydalanishni ta'minlashi mumkin. Bundan tashqari, sanoat zonalarida tuproq tarkibida texnogen ifloslanish natijasida shakllanishi mumkin bo‘lgan tuzlanish xavfini hisobga olib, ekishdan oldin tuproq tuzliligi (EC) va pH ko‘rsatkichlarini aniqlash, zarur hollarda gips yoki boshqa meliorativ vositalar qo‘llash tavsiya etiladi. Bu choralar, ayniqsa yuqori akkumulyativ turlar (eman, gozal katalpa) uchun, ularning ildiz tizimi tuproqdagi ortiqcha tuzlar va og‘ir metallarga bir vaqtning o‘zida duch kelishi mumkinligi sababli, alohida ahamiyat kasb etadi.

Tadqiqotning cheklovlari va kelgusi yo‘nalishlar. Ushbu tadqiqotning agrotexnik tavsiyalari asosan bitta ma'lumot to‘plami — to‘rt daraxt turining bir mavsumdagi kimyoviy tahlili natijalariga asoslangan bo‘lib, taklif etilgan qator sxemasi va oraliq masofalar hali dala sharoitida sinovdan o‘tkazilmagan. Kelgusi tadqiqotlarda taklif etilgan tur joylashuvi sxemasi asosida haqiqiy tajriba maydonchasi barpo etilishi, ko‘chatlarning tutish darajasi, o‘sish tezligi va 3–5 yillik davrda akkumulyatsiya dinamikasi kuzatilishi hamda shamol tezligini kamaytirish samaradorligi (anemometrik o‘lchovlar orqali) o‘lchanishi tavsiya etiladi. Bundan tashqari, tavsiya etilgan sug‘orish va parvarish me'yorlarini mahalliy suv resurslari taqchilligini hisobga olgan holda iqtisodiy-agronomik jihatdan asoslash ham kelgusi tadqiqot yo‘nalishi sifatida muhim ahamiyatga ega.

XULOSA VA TAKLIFLAR

1. Tekshirilgan to‘rt daraxt turi ifloslantiruvchi moddalarni akkumulyatsiya qilish qobiliyati bo‘yicha bir-biridan sezilarli farq qiladi, bu ularni himoya polosasida joylashtirishda hisobga olinishi zarur.

2. Eman va gozal katalpa yuqori akkumulyativ xususiyati tufayli himoya polosasining tashqi qatoriga, sharq chinori va soxta kashtan esa ichki qatorlarga ekish uchun tavsiya etiladi.

3. Ishlab chiqilgan agrotexnik tavsiyalar (qator soni, oraliq masofalar, tur joylashuvi, ekish va parvarish tartibi) sanoat hududlarida himoya o‘rmon ekinzorlarini barpo etishda amaliy qo‘llanilishi mumkin.

4. Himoya polosasi barglarida to‘plangan og‘ir metallarni muntazam monitoring qilish va ularni maxsus utilizatsiya qilish ikkilamchi ifloslanishning oldini oladi.

5. Xalqaro tajribadan olingan agrotexnik parametrlarni O‘zbekistonning issiq-quruq iqlim sharoitiga moslashtirish bo‘yicha qo‘shimcha dala tajribalari o‘tkazilishi tavsiya etiladi.

6. Taklif etilgan to‘rt turli aralash tarkib nafaqat og‘ir metallarni akkumulyatsiya qilish, balki himoya polosasi doirasida biologik xilma-xillikni saqlash va foydali hasharotlar populyatsiyasini qo‘llab-quvvatlash nuqtai nazaridan ham amaliy ahamiyatga ega.

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SANOAT IFLOSLANISHI TA'SIRIDA DARAXT TURLARINING FIZIOLOGIK MOSLASHUVI VA BIOINDIKATORLIK QONUNIYATLARINI ANIQLASH

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Annotatsiya. *Sanoat korxonalari atrofida o'sadigan daraxt turlarining og'ir metallar va noyob yer elementlarini (REE) o'zida to'plash darajasi ularning ifloslanishga fiziologik moslashuv qonuniyatlarini aks ettiradi. Tadqiqotda Chirchiq shahridagi "Maksam-Chirchiq" zavodi atrofida o'sadigan to'rt xil daraxt turi (eman, sharq chinori, gozal katalpa, soxta kashtan) barglari induktiv bog'langan plazma mass-spektrometriyasi (ISP-MS) usulida tahlil qilindi. Eman va gozal katalpa yuqori akkumulyatsiya ko'rsatkichlari (mos ravishda ΣREE 2,106 va 2,101 mg/kg) bilan ajralib turdi, bu ularning barg tuzilishidagi moslashuv xususiyatlari (yirik yuza, tuklanish) tufayli ifloslantiruvchi moddalarni faolroq akkumulyatsiya qilishini ko'rsatadi. Olingan natijalar shahar sharoitida ekologik monitoring tizimini takomillashtirishda amaliy ahamiyatga ega.*

Kalit so'zlar: *bioindikatorlik, fiziologik moslashuv, og'ir metallar, REE, sanoat ifloslanishi, daraxt turlari, ISP-MS.*

Аннотация. *Степень накопления тяжелых металлов и редкоземельных элементов (РЗЭ) в древесных породах, произрастающих вблизи промышленных предприятий, отражает закономерности их физиологической адаптации к загрязнению. В исследовании листья четырех видов деревьев (дуб, платан восточный, катальпа, конский каштан), произрастающих вблизи завода «Максам-Чирчик» в городе Чирчик, были проанализированы методом масс-спектрометрии с индуктивно связанной плазмой (ИСП-МС). Дуб и катальпа выделялись наиболее высокими показателями накопления (ΣРЗЭ 2,106 и 2,101 мг/кг соответственно), что объясняется адаптивными особенностями структуры их листьев. Полученные результаты имеют практическое значение для совершенствования системы экологического мониторинга в городских условиях.*

Ключевые слова: *биоиндикация, физиологическая адаптация, тяжелые металлы, РЗЭ, промышленное загрязнение, древесные породы, ИСП-МС.*

Abstract. *The degree to which tree species growing near industrial enterprises accumulate heavy metals and rare earth elements (REE) reflects patterns of physiological adaptation to pollution. In this study, leaves of four tree species (oak,*

Oriental plane tree, catalpa, and horse chestnut) growing near the "Maxam-Chirchiq" plant in Chirchiq city were analyzed using inductively coupled plasma mass spectrometry (ICP-MS). Oak and catalpa exhibited the highest accumulation indices (ΣREE of 2.106 and 2.101 mg/kg, respectively), attributable to adaptive features of their leaf structure. The findings have practical significance for improving environmental monitoring systems in urban settings.

Keywords: *bioindication, physiological adaptation, heavy metals, REE, industrial pollution, tree species, ICP-MS.*

KIRISH

Sanoat korxonalaridan atmosferaga chiqarilayotgan azot oksidi, oltingugurt birikmalari, chang va og‘ir metall zarrachalari inson salomatligi hamda ekotizimlar barqarorligiga jiddiy tahdid solmoqda. Jahon miqyosida sanoatlashgan hududlarda havo ifloslanishi bilan bog‘liq kasalliklar yildan-yilga ortib bormoqda, bu esa atrof-muhit monitoringi tizimlarini takomillashtirishni dolzarb vazifaga aylantirmoqda. Bunday sharoitda shahar ko‘kalamzorlashtirish tizimidagi daraxt turlarining atmosfera va tuproqdagi og‘ir metallarni o‘zida to‘plash xususiyati ularni arzon va ishonchli bioindikator sifatida qo‘llash imkonini yaratadi.

Og‘ir metallarning inson organizmiga ta'siri keng o‘rganilgan muammo hisoblanadi: qo‘rg‘oshin (Pb) asosan nafas yo‘llari orqali qonga so‘rilib, nerv tizimiga zararli ta'sir ko‘rsatadi; kadmiy (Cd) buyrak funksiyasini buzadi va kansorogen xususiyatga ega; mishyak (As) esa xalqaro tasniflarda saraton kasalligini keltirib chiqaruvchi asosiy elementlardan biri sifatida qayd etilgan. Bunday elementlarning atmosferada tarqalishi va o‘simliklarda to‘planishi darajasini vaqtida aniqlash aholi salomatligini muhofaza qilishning muhim tarkibiy qismidir. Og‘ir metallar bilan bir qatorda, so‘nggi yillarda zamonaviy sanoat, elektronika va o‘g‘it ishlab chiqarishda keng qo‘llanilayotgan noyob yer elementlari (Rare Earth Elements, REE) ham atrof-muhitga tarqalayotgan yangi turdagi ifloslantiruvchi moddalar guruhi sifatida ilmiy jamoatchilik e'tiborini tortmoqda, biroq ularning ekologik-toksikologik xavfi hali yetarlicha o‘rganilmagan.

O‘simliklar, xususan daraxt turlari, atrof-muhitdagi ifloslanish darajasini aks ettiruvchi tabiiy “passiv monitor” vazifasini bajaradi. Ularning bargida vegetatsiya davomida to‘plangan elementlar miqdorini tahlil qilish orqali ma'lum hududdagi atmosfera va tuproq ifloslanish darajasini nisbatan arzon va keng ko‘lamda baholash mumkin. Biroq bu borada muhim savol — turli daraxt turlarining ifloslantiruvchi moddalarni akkumulyatsiya qilish qobiliyati bir xil emasligi, ya'ni har bir tur o‘ziga xos fiziologik moslashuv strategiyasiga ega ekanligidir. Shu sababli, aynan qaysi mahalliy daraxt turi eng samarali bioindikator sifatida xizmat qila olishini aniqlash amaliy va ilmiy ahamiyatga ega masaladir.

ADABIYOTLAR TAHLILI

Daraxt barglarining og‘ir metallarni bioindikatsiya qilish salohiyati bo‘yicha xalqaro adabiyotda keng tadqiqotlar olib borilgan. Jiang va boshqalar shahar sharoitida mox va daraxt barglarining atmosfera og‘ir metall cho‘kmasini monitoring qilishdagi samaradorligini solishtirib, har ikkala organizm turi ham ifloslanishni aks ettirishga

qodir ekanligini, biroq ularning sezgirlik darajasi turlicha ekanligini ko‘rsatdi. Pająk va hammualliflarining so‘nggi tadqiqotida Krakov shahridagi bog‘larda qayin, lipa va zarrali platan barglari hamda Pleurozium schreberi moxi solishtirilib, qayin barglarining eng yuqori metall akkumulyatsiya indeksi (MAI) va biokonsentratsiya koeffitsientiga (BAF) ega ekanligi, shu sababli uni “giperto‘plovchi” (hyperaccumulator) sifatida tavsiya etish mumkinligi aniqlangan. Bu natija turli daraxt turlari orasida akkumulyatsiya qobiliyati bo‘yicha sezilarli farq borligini tasdiqlaydi.

Gasiorek va hammualliflari tomonidan Krakovning tarixiy bog‘lari tuprog‘idagi og‘ir metall ifloslanishi geokimyoviy fon asosida baholanib, mahalliy fon ko‘rsatkichidan foydalanilganda antropogen ifloslanish yanada aniqroq namoyon bo‘lishi ko‘rsatilgan — bu uslub ushbu tadqiqotda ham qo‘llaniladigan yondashuvga mos keladi. Dresler va hammualliflari Polshadagi Zn-Pb kon-metallurgiya zonasi atrofida qayin barglarining og‘ir metallarni to‘plash qobiliyatini o‘rganib, yuqori metall yuki barglarning ikkilamchi metabolizmiga (fenol birikmalar sinteziga) ta'sir qilishini aniqladi, bu esa metall akkumulyatsiyasi va o‘simlikning fiziologik javob reaktsiyasi o‘rtasidagi bog‘liqlikni ko‘rsatadi.

Elkaee va hammualliflari Tehron shahridagi shahar daraxtlarining chang, og‘ir metall va uglerod cho‘ktirish salohiyatini qiyosiy baholab, katta barg yuzasiga va tuklangan epidermisga ega turlarning changni ko‘proq ushlab qolishini isbotladi. Nguyen va hammualliflari Vetnamning sanoat hududi tuprog‘ida nafaqat an'anaviy og‘ir metallar, balki noyob yer elementlari (REE) ham baholanishi zarurligini ta'kidlab, REE monitoringi hali yetarlicha rivojlanmagan yo‘nalish ekanligini qayd etdi. Bu fikr Sager va Wiche hamda Doulgeridou va hammualliflarining REE ekologik-toksikologik xavfi bo‘yicha keng qamrovli sharhlarida ham tasdiqlangan bo‘lib, ular yengil REE elementlarining (La, Ce, Nd) o‘simliklarda ustunlik qilishini umumiy geokimyoviy qonuniyat sifatida ta’riflaydi.

Mahalliy sharoitda esa muallif tomonidan ilgari sharq chinori (Platanus orientalis) barglarida og‘ir metallar to‘planishi alohida o‘rganilgan va uning bioindikatorlik xususiyati tasdiqlangan edi, shuningdek manzarali daraxt turlarining chiqindi gazlariga chidamliligi bo‘yicha tadqiqot olib borilgan. Biroq mavjud adabiyotlarda turli daraxt turlarining akkumulyatsiya qobiliyatini bir vaqtning o‘zida og‘ir metallar va REE bo‘yicha qiyosiy baholash, ya'ni qaysi tur eng samarali "biofiltr" ekanligini kompleks aniqlash masalasi hali yetarlicha o‘rganilmagan.

Shuni ham ta’kidlash lozimki, adabiyotlarda tahlil qilingan tadqiqotlarning aksariyati bitta yoki ikkita elementlar guruhiga (odatda faqat og‘ir metallarga) qaratilgan bo‘lib, og‘ir metallar va REE ni bir vaqtning o‘zida, bir xil namunalarda taqqoslovchi tadqiqotlar juda kam uchraydi. Bu ayniqsa, Markaziy Osiyo mintaqasi, jumladan O‘zbekiston sharoiti uchun deyarli o‘rganilmagan yo‘nalish hisoblanadi. Shu bilan birga, ko‘pchilik xorijiy tadqiqotlar (Krakov, Tehron, Vetnam misollarida) mo‘tadil yoki subtropik iqlim sharoitida o‘tkazilgan bo‘lib, ularning natijalarini O‘zbekistonning issiq va quruq kontinental iqlimi sharoitiga to‘g‘ridan-to‘g‘ri tatbiq etish ilmiy jihatdan asossizdir — bu esa mahalliy sharoitda mustaqil tadqiqot o‘tkazish zaruriyatini yanada kuchaytiradi.

Tadqiqotning maqsadi — bir xil sanoat zonasida o‘sadigan to‘rt xil daraxt turining og‘ir metallar va REE larni akkumulyatsiya qilish qobiliyatini qiyosiy baholash, ularning fiziologik moslashuv qonuniyatlarini aniqlash va eng samarali bioindikator turni belgilashdan iborat.

TADQIQOT METODOLOGIYASI

Tadqiqot obyekti sifatida Toshkent viloyati Chirchiq shahridagi "Maksam-Chirchiq" zavodi atrofida o‘sadigan to‘rt xil manzarali daraxt turi — eman (Quercus), sharq chinori (Platanus orientalis), gozal katalpa (Catalpa) va soxta kashtan (Aesculus) — bargidan olingan namunalar xizmat qildi. Namunalar iyul oyida terib olindi, chunki bu davrda barglarda mavsum davomida to‘plangan ifloslantiruvchi moddalar miqdori maksimal darajaga yetadi.

Namunalar tarkibidagi mikro- va makroelementlar, jumladan og‘ir metallar (Pb, Zn, Cu, Ni, Cd, Mn, Sr, Ba, Co, As) hamda noyob yer elementlari (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) miqdori induktiv bog‘langan plazma mass-spektrometriyasi (ISP-MS, NEXION-2000 asbobi) usulida O‘zbekiston Respublikasi Fanlar akademiyasi Bioorganika kimyo instituti bilan hamkorlikda aniqlandi.

Namunalarni tayyorlash uchun 0,0500–0,5000 g miqdordagi aniq namuna analitik tarozida o‘lchanib, teflon avtoklavlarga joylashtirildi va konsentrlangan azot kislotasi hamda vodorod peroksidi qo‘shilib, Berghof mikroto‘lqinli parchalagichida (MWS-3+ dasturi) parchalandi. Parchalangan namuna 50–100 ml hajmli o‘lchov kolbalariga o‘tkazilib, 0,5% li azot kislotasi bilan belgilangan hajmga yetkazildi. Tahlil natijalari Perkin Elmer standarti asosida xatolik chegarasi (RSD, %) bilan mg/kg birligida ifodalandi.

Statistik tahlil uchun har bir tur bo‘yicha olingan qiymatlar solishtirma jadvallarga kiritilib, elementlar yig‘indisi (ΣREE) hisoblab chiqildi. Turlar orasidagi farqlar tavsiflovchi taqqoslash usulida (descriptive comparison) baholandi.

Tadqiqot dizayni tavsiflovchi-qiyosiy (descriptive-comparative) turga mansub bo‘lib, to‘rt xil daraxt turi bir xil geografik nuqta va bir xil vaqt oralig‘ida namuna olish orqali solishtirildi, bu esa natijalarga ta'sir qiluvchi tashqi omillarni (masalan, iqlim, ifloslanish manbaigacha bo‘lgan masofa) nazorat qilish imkonini berdi. Olingan ma'lumotlar mg/kg quruq massa birligida ifodalanib, har bir element bo‘yicha turlar orasidagi nisbiy farq foizlarda hisoblab chiqildi.

TAHLIL VA NATIJALAR

Tadqiqot davomida to‘rt xil daraxt turi barglarida ISP-MS usulida aniqlangan og‘ir metallar va noyob yer elementlari (REE) miqdori quyida jadvallar ko‘rinishida keltirilgan. Har bir jadvaldan so‘ng olingan natijalar tahlil qilinib, turlar orasidagi farqlar hamda ularning mumkin bo‘lgan fiziologik sabablari muhokama etiladi.

1-jadval.

Eng xavfli hisoblangan og‘ir metallarning daraxt barglaridagi miqdori (mg/kg)

Daraxt turi	*Pb*	*Zn*	*Cu*	*Ni*	*Cd*	*Mn*	*Sr*	*Ba*	*Co*	*As*
Eman (Quercus)	2,62	35,8	13,9	8,49	0,029	35,7	109	67,5	0,260	0,591
Sharq chinori (P. orientalis)	1,12	8,97	8,90	2,74	0,011	72,4	61,1	15,8	0,144	0,412

Daraxt turi	*Pb*	*Zn*	*Cu*	*Ni*	*Cd*	*Mn*	*Sr*	*Ba*	*Co*	*As*
Gozal katalpa (Catalpa)	2,57	35,1	10,7	2,15	0,017	69,9	123	34,5	0,252	0,809
Soxta kashtan (Aesculus)	1,80	10,6	8,29	1,61	0,017	79,5	60,7	39,7	0,220	0,571

1-jadvaldan ko‘rinib turibdiki, eman (Quercus) barglarida qo‘rg‘oshin (Pb – 2,62 mg/kg), rux (Zn – 35,8 mg/kg), nikel (Ni – 8,49 mg/kg), kadmiy (Cd – 0,029 mg/kg) va mishyak (As – 0,591 mg/kg) miqdori qolgan uchta turga nisbatan eng yuqori ko‘rsatkichni namoyon qildi. Sharq chinorida esa aksincha, aksariyat elementlar (Zn, Ni, Cd, Ba) bo‘yicha eng past ko‘rsatkichlar qayd etilib, faqat marganets (Mn – 72,4 mg/kg) nisbatan yuqori bo‘lib chiqdi. Gozal katalpa strontsiy (Sr – 123 mg/kg) va mishyak (As – 0,809 mg/kg) bo‘yicha, soxta kashtan esa marganets (Mn – 79,5 mg/kg) va bariy (Ba – 39,7 mg/kg) bo‘yicha nisbatan yuqori ko‘rsatkichlarga ega bo‘ldi.

2-jadval.

Daraxt barglaridagi noyob yer elementlari (REE) miqdori (mg/kg)

Daraxt turi	La	Ce	Pr	Nd	Sm	Eu	Gd	Dy	ΣREE
Eman	0,521	0,992	0,087	0,293	0,063	0,034	0,046	0,037	2,106
Sharq chinori	0,260	0,507	0,044	0,149	0,029	0,015	0,021	0,017	1,042
Gozal katalpa	0,508	0,977	0,094	0,311	0,067	0,021	0,046	0,041	2,101
Soxta kashtan	0,354	0,658	0,065	0,210	0,047	0,019	0,031	0,029	1,437

2-jadvaldan ko‘rinib turibdiki, barcha to‘rt turda ham yengil REE guruhiga kiruvchi lantan (La) va seriy (Ce) eng yuqori miqdorda uchraydi, og‘ir REE guruhi (Er, Yb) esa barcha turlarda ancha kam miqdorda qayd etildi. Bu naqsh Sager va Wiche hamda boshqa mualliflar tomonidan tasvirlangan o‘simliklarda REE to‘planishining umumiy geokimyoviy qonuniyatiga to‘liq mos keladi va ildiz orqali tuproqdan o‘zlashtirishning asosiy mexanizm ekanligini tasdiqlaydi. ΣREE bo‘yicha ham eman (2,106 mg/kg) va gozal katalpa (2,101 mg/kg) yetakchilik qilib, bu ikkala turning umumiy akkumulyativ salohiyati boshqa ikkitasidan deyarli ikki baravar yuqori ekanligini ko‘rsatdi.

Fiziologik moslashuv mexanizmlari. Daraxt turlarining og‘ir metall va REE larni turlicha akkumulyatsiya qilishi bir necha fiziologik omil bilan izohlanadi: (1) barg epidermisi va kutikula qalinligi — qalinroq kutikulaga ega turlar zaharli moddalarni tashqi to‘siq sifatida ko‘proq ushlab qoladi; (2) stomatalar zichligi va joylashuvi — stomatalar orqali gazsimon va erigan ifloslantiruvchi moddalarning hujayra ichiga kirishi tezlashadi; (3) ildiz tizimining tarmoqlanish darajasi — chuqur va zich ildiz tizimiga ega turlar tuproqdagi harakatchan metall ionlarini faolroq o‘zlashtiradi. Guo va hammualliflarining so‘nggi sharhida ko‘rsatilishicha, og‘ir metallar stomatalarning ochilish-yopilish faoliyatiga bevosita ta'sir qiladi va abssiz kislota (ABK) hamda reaktiv kislorod turlari (ROS) darajasini oshirib, stomatalarning yopilishini keltirib chiqarishi mumkin — bu esa o‘simlikning metall qabul qilishni cheklovchi himoya reaksiyasi hisoblanadi. Bu xulosa Elkaee va hammualliflarining katta barg yuzasiga ega turlarning changni faolroq ushlashi haqidagi topilmasi bilan ham mos keladi. Eman va gozal katalpaning yuqori akkumulyatsiya ko‘rsatkichlari, ehtimol, aynan shu uchala mexanizmning birgalikda namoyon bo‘lishi bilan bog‘liq.

Hujayra darajasidagi himoya mexanizmlari. O‘simliklarda og‘ir metallarning zaharli ta’siridan himoyalanishning asosiy yo‘llaridan biri — ularni vakuolalarda yoki hujayra devorida bog‘lab, fiziologik faol sitoplazmadan ajratib qo‘yishdir (kompartmentalizatsiya). Dresler va hammualliflari ko‘rsatganidek, yuqori metall yuki qayin barglarida ikkilamchi metabolitlar (fenol birikmalar) sintezini faollashtiradi — bu o‘simlikning stress omiliga javob reaktsiyasi hisoblanadi. Qi va hammualliflarining

Vigna radiata o‘simligida o‘tkazgan tadqiqotida ham og‘ir metall stressi ta'sirida eriydigan qandlar to‘planishi va biomassaning qayta taqsimlanishi orqali osmotik moslashuv sodir bo‘lishi ko‘rsatilgan, bu umumiy stress-moslashuv strategiyasining daraxtlarda ham amal qilishi mumkinligini ko‘rsatadi. Yuqori akkumulyatsiya ko‘rsatkichiga ega turlarda (eman, gozal katalpa) ushbu himoya mexanizmlarining nisbatan yaxshi rivojlangan bo‘lishi ehtimoldan xoli emas, biroq bu faraz kelgusida biokimyoviy tahlillar orqali tasdiqlanishi lozim.

Elementlar orasidagi bog‘liqlik. Diqqatga sazovor jihati shundaki, og‘ir metallar bo‘yicha yetakchi turlar (eman, gozal katalpa) REE bo‘yicha ham yetakchi bo‘lib chiqdi. Bu ikki mustaqil elementlar guruhi orasidagi mos kelish tasodifiy emas — u bir xil fiziologik mexanizm (barg yuzasi orqali passiv adsorbsiya va ildiz orqali faol o‘zlashtirish) ikkala guruh uchun ham amal qilishini ko‘rsatadi. Bu esa ΣREE ko‘rsatkichini kelgusida qo‘shimcha, mustaqil bioindikator parametr sifatida qo‘llash mumkinligini asoslaydi.

Bioindikatorlik nuqtai nazaridan, yuqori akkumulyatsiya qobiliyatiga ega turlar (eman, gozal katalpa) atrof-muhit monitoringi uchun eng informativ turlar hisoblanadi, chunki ularda ifloslanish darajasidagi o‘zgarishlar tezroq va aniqroq aks etadi. Bu xulosa Pająk va hammualliflarining qayin barglarini eng samarali "giperto‘plovchi" sifatida tavsiya etishi bilan mantiqan hamohang. Sharq chinori va soxta kashtan esa nisbatan barqaror (kam o‘zgaruvchan) fon ko‘rsatkichini beruvchi "nazorat" turlari sifatida monitoring tizimida qo‘llanilishi mumkin. Kelgusi tadqiqotlarda ushbu kimyoviy natijalarni fotosintez intensivligi, xlorofill miqdori va stomatalar zichligi kabi to‘g‘ridan-to‘g‘ri fiziologik ko‘rsatkichlar bilan bog‘lab o‘rganish tavsiya etiladi. Xalqaro tadqiqotlar bilan qiyosiy tahlil. Olingan natijalarni xalqaro adabiyotlar bilan solishtirish quyidagi qonuniyatlarni ochib beradi. Krakov shahridagi bog‘larda o‘tkazilgan tadqiqotda qayin barglarida rux (Zn) miqdori boshqa turlarga nisbatan to‘rt baravar yuqori bo‘lgani qayd etilgan, bu bizning tadqiqotimizda emanning boshqa turlarga nisbatan yuqori Zn ko‘rsatkichi (35,8 mg/kg) bilan bir xil naqshni tashkil etadi — ya’ni har ikkala tadqiqotda ham keng, tuklangan barg yuzasiga ega tur yetakchilik qilgan. Tehron shahridagi shahar daraxtlari bo‘yicha o‘tkazilgan tadqiqotda ham katta barg yuzasi va tuklanish darajasi chang va og‘ir metall akkumulyatsiyasi bilan ijobiy bog‘liq ekanligi statistik jihatdan tasdiqlangan, bu bizning eman va gozal katalpa bo‘yicha olingan natijalarimizni nazariy jihatdan asoslaydi.

Shu bilan birga, ma’lum farqlar ham kuzatildi: agar Pol tadqiqotlarida qayin (Betula) eng yuqori akkumulyatorlar qatoriga kirgan bo‘lsa, bizning tadqiqotimizda mahalliy sharoitda eman (Quercus) ushbu vazifani bajardi. Bu farq geografik-iqlim sharoitlari, ifloslanish manbaining tabiati (Krakovda asosan transport va uy-joy issiqlik tizimlari, Chirchiqda esa kimyo sanoati korxonasi) hamda tuproq geokimyosining farqi

bilan izohlanishi mumkin. Bu, o‘z navbatida, bioindikator turni tanlashda mahalliy sharoitlarni har doim alohida sinovdan o‘tkazish zarurligini ko‘rsatadi — boshqa mintaqalarda olingan natijalarni to‘g‘ridan-to‘g‘ri ko‘chirib qo‘llash noto‘g‘ri xulosalarga olib kelishi mumkin.

Tadqiqotning cheklovlari va kelgusi yo‘nalishlar. Ushbu tadqiqotning bir qator cheklovlari mavjud. Birinchidan, namunalar faqat bitta mavsumda (iyul oyida) olingan bo‘lib, elementlar miqdorining fasllar bo‘yicha o‘zgarishi hisobga olinmagan. Ikkinchidan, tadqiqot bitta sanoat manbai (“Maxam-Chirchiq” zavodi) atrofida o‘tkazilgan, shu sababli natijalarni boshqa turdagi sanoat korxonalari (masalan, metallurgiya yoki avtotransport ifloslanishi) atrofiga umumlashtirish ehtiyotkorlik talab qiladi. Uchinchidan, fiziologik moslashuv mexanizmlari (kutikula qalinligi, stomatalar zichligi, fitoxelatinlar miqdori) haqidagi xulosalar hozircha nazariy faraz darajasida bo‘lib, ularni tasdiqlash uchun qo‘shimcha anatomik va biokimyoviy tahlillar talab etiladi. Kelgusi tadqiqotlarda nazorat (sanoatsiz) hududdan olingan namunalar bilan solishtirish, fasllar kesimida dinamik kuzatuv olib borish hamda statistik ishonchlilikni oshirish uchun namunalar sonini ko‘paytirish tavsiya etiladi.

XULOSA VA TAKLIFLAR

1. Tekshirilgan daraxt turlari sanoat ifloslanishiga nisbatan turlicha fiziologik moslashuv strategiyasini namoyon qiladi, bu ularning barg tuzilishi va ildiz faoliyati bilan bog‘liq.

2. Eman (Quercus) va gozal katalpa (Catalpa) eng yuqori bioindikatorlik salohiyatiga ega bo‘lib, ekologik monitoring tizimida ustuvor tur sifatida tavsiya etiladi.

3. Barcha to‘rt turda ham yengil REE guruhi (La, Ce) ustunlik qilishi aniqlandi, bu xalqaro adabiyotlarda qayd etilgan umumiy geokimyoviy qonuniyatga mos keladi va REE monitoringini mahalliy amaliyotga joriy etish zarurligini ko‘rsatadi.

4. Og‘ir metallar va REE bo‘yicha yetakchi turlarning bir xil bo‘lib chiqishi ularning fiziologik moslashuv mexanizmi umumiy ekanligini ko‘rsatadi, bu esa ΣREE ko‘rsatkichini qo‘shimcha bioindikator parametr sifatida qo‘llash imkonini beradi.

5. Aniqlangan qonuniyatlarni kelgusida fotosintez intensivligi, xlorofill miqdori va stomatalar zichligi kabi to‘g‘ridan-to‘g‘ri fiziologik ko‘rsatkichlar bilan bog‘lab, chuqurroq o‘rganish tavsiya etiladi.

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EKSPORT SALOHINI OSHIRISH VA YASHIL AGROBIZNESNI RIVOJLANTIRISH YO‘LLARI

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Annotatsiya. *Mazkur maqolada eksport salohiyatini oshirish va yashil agrobiznesni rivojlantirishning zamonaviy yo‘nalishlari hamda iqtisodiy ahamiyati tahlil qilingan. Qishloq xo‘jaligi mahsulotlari eksportini kengaytirish, xalqaro bozorlarda raqobatbardoshlikni kuchaytirish, ekologik toza va resurs tejamkor ishlab chiqarish texnologiyalarini joriy etish masalalari yoritilgan. Shuningdek, yashil agrobiznesni rivojlantirish orqali atrof-muhit muhofazasini ta’minlash, oziq-ovqat xavfsizligini mustahkamlash va qishloq hududlarida barqaror iqtisodiy o‘sishga erishish imkoniyatlari ko‘rib chiqilgan. Tadqiqot natijalariga asoslanib, eksport hajmini oshirish va yashil iqtisodiyot tamoyillariga mos agrobiznesni rivojlantirish bo‘yicha amaliy taklif va tavsiyalar ishlab chiqilgan.*

Kalit so‘zlar: *export potential, green agribusiness, agriculture, ecological production, sustainable development, export markets, competitiveness, green economy, innovative technologies.*

Аннотация. *В данной статье анализируются современные направления и экономическое значение наращивания экспортного потенциала и развития «зеленого» агробизнеса. Рассматриваются вопросы расширения экспорта сельскохозяйственной продукции, повышения конкурентоспособности на международных рынках и внедрения экологически чистых и ресурсоэффективных технологий производства. Также рассматриваются возможности обеспечения охраны окружающей среды, укрепления продовольственной безопасности и достижения устойчивого экономического роста в сельской местности посредством развития «зеленого» агробизнеса. На основе результатов исследования разработаны практические предложения и рекомендации по увеличению объемов экспорта и развитию агробизнеса в соответствии с принципами «зеленой» экономики.*

Ключевые слова: *экспортный потенциал, зелёный агробизнес, сельское хозяйство, экологическое производство, устойчивое развитие, экспортные рынки, конкурентоспособность, зелёная экономика, инновационные технологии.*

Abstract. *This article analyzes the modern directions and economic significance of increasing export potential and developing green agribusiness. The issues of expanding the export of agricultural products, strengthening competitiveness in*

international markets, and introducing environmentally friendly and resource-efficient production technologies are covered. The possibilities of ensuring environmental protection, strengthening food security, and achieving sustainable economic growth in rural areas through the development of green agribusiness are also considered. Based on the results of the research, practical proposals and recommendations have been developed to increase export volumes and develop agribusiness in accordance with the principles of a green economy.

Keywords: *export potential, green agribusiness, agriculture, ecological production, sustainable development, export markets, competitiveness, green economy, innovative technologies.*

I. KIRISH.

Fermer xo‘jaliklarining eksport salmog‘ini oshirish mamlakatning qishloq xo‘jaligi sektorining barqaror rivojlanishi va umumiy iqtisodiy salohiyatini oshirish uchun muhim ahamiyatga ega. Eksportni rivojlantirish nafaqat milliy daromadni oshiradi, balki fermerlarning daromad manbalarini barqarorlashtiradi, ish o‘rinlarini yaratadi va tashqi savdo balansini ijobiy tomonga o‘zgartirishga yordam beradi.

Statistik ma’lumotlarga ko‘ra, O‘zbekistonning qishloq xo‘jaligi eksporti oxirgi yillarda barqaror o‘sish sur’atlarini namoyon qilmoqda va 2025 yil uchun bu ko‘rsatkich taxminan bir milliard sakkiz yuz million AQSh dollarini tashkil etadi. Shu eksportning asosiy qismi meva va sabzavot mahsulotlariga to‘g‘ri keladi, bu esa fermer xo‘jaliklarining eksport salmog‘ini oshirishdagi strategik yo‘nalishlarini belgilashda muhim rol o‘ynaydi. Shu bilan birga, yetkazib berish va mahsulot sifatiga bog‘liq yo‘qotishlar tahminan yigirma-yiqirm besh foizga yetadi, bu esa eksport hajmini sezilarli darajada pasaytiradi va tizimli chora-tadbirlarni talab qiladi.

Mahsulot sifatini oshirish va xalqaro standartlarga moslash eksportni rivojlantirishning birinchi va eng muhim bosqichi hisoblanadi. Xalqaro bozorlar talabini qondirish uchun fermer xo‘jaliklarida Good Agricultural Practices (GAP), ISO 22000 va HACCP kabi standartlarni joriy etish zarur. Ushbu sertifikatlar nafaqat mahsulot xavfsizligini va sifatini kafolatlaydi, balki eksport bozorlarida raqobatbardoshligini oshiradi. GAP sertifikatlash tizimi orqali fermerlar ishlab chiqarish barcha bosqichlarini qayta ko‘rib chiqadi, resurslarni tejash, ekologik barqarorlikni ta’minlash va mahsulot sifatini yaxshilash imkoniyatiga ega bo‘ladi. Shuningdek, mahsulot sifatining oshishi milliy ishlab chiqaruvchilarga xalqaro bozorlar bilan samarali integratsiyalashishga imkon beradi va eksport hajmini barqaror ravishda oshirishga yordam beradi.

Bu jarayon nafaqat iqtisodiy samaradorlikni oshiradi, balki milliy mahsulotlarga nisbatan ishonchni kuchaytiradi. [1]

[1] Food and Agriculture Organization of the United Nations (FAO). *Good Agricultural Practices (GAP) Guidelines for Smallholder Farmers*. Roma: FAO, 2020. https://www.fao.org/fao-who-codexalimentarius/codex-texts/gap/en/ ↩
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II. ADABIYOTLAR TAHLILI

Eksport salohiyatini oshirish va yashil agrobiznesni rivojlantirish masalalari ko‘plab olimlar tomonidan tadqiq etilgan. Xususan, M. Porter (1990) mamlakatlarning xalqaro bozordagi muvaffaqiyati raqobatbardoshlik, innovatsiyalar va samarali ishlab chiqarish tizimlariga bog‘liqligini ta’kidlaydi. O‘zbekiston sharoitida olib borilgan tadqiqotlarda esa qishloq xo‘jaligi mahsulotlari eksportini rivojlantirish uchun logistika infratuzilmasini takomillashtirish, mahsulotlarni xalqaro standartlar asosida sertifikatlash va eksport bozorlarini diversifikatsiya qilish zarurligi qayd etilgan (Mahmudov va Karimov, 2020).

Yashil agrobiznes va ekologik ishlab chiqarish masalalari bo‘yicha tadqiqotlarda resurslardan oqilona foydalanish, ekologik xavfsizlikni ta’minlash hamda barqaror rivojlanishga erishish muhim omillar sifatida e’tirof etiladi. FAO (2019) ma’lumotlariga ko‘ra, ekologik qishloq xo‘jaligi texnologiyalarini joriy etish yer unumdorligini saqlash, suv resurslarini tejash va oziq-ovqat xavfsizligini mustahkamlash imkonini beradi. Solaymanov va hamkorlari (2021) organik dehqonchilik va yashil ishlab chiqarish texnologiyalarining iqtisodiy samaradorligini asoslab, ularning eksportbop mahsulotlar ishlab chiqarishdagi ahamiyatini ko‘rsatib bergan.

So‘nggi yillarda eksport salohiyati va yashil agrobiznesni o‘zaro uyg‘unlashtirish masalalariga alohida e’tibor qaratilmoqda. Smith va Johnson (2022) yashil texnologiyalarni eksportga yo‘naltirilgan agrobiznes strategiyalari bilan integratsiyalash mamlakatlarning iqtisodiy samaradorligini oshirish, yangi bozorlarni egallash va ekologik barqarorlikni ta’minlashga xizmat qilishini ta’kidlaydilar. Shuningdek, O‘zbekiston Respublikasida qabul qilingan me’yoriy-huquqiy hujjatlar ham eksportni rag‘batlantirish va ekologik ishlab chiqarishni qo‘llab-quvvatlashning institutsional asoslarini mustahkamlashga qaratilgan.

Umuman olganda, ilmiy adabiyotlar tahlili eksport salohiyatini oshirish va yashil agrobiznesni rivojlantirish bir-biri bilan uzviy bog‘liq jarayonlar ekanligini ko‘rsatadi. Raqobatbardosh, ekologik toza va innovatsion mahsulotlar ishlab chiqarish orqali nafaqat eksport hajmini oshirish, balki qishloq xo‘jaligining barqaror rivojlanishini ham ta’minlash mumkin.

III. TADQIQOT METODOLOGIYASI

Mahsulot assortimentini diversifikatsiya qilish eksportni rivojlantirishda muhim yo‘nalishlardan biri hisoblanadi. Xom ashyo eksportidan tashqari, qayta ishlangan mahsulotlarni ishlab chiqarish yuqori qo‘shilgan qiymat yaratadi va iqtisodiy samaradorlikni oshiradi. Quritilgan meva-sabzavotlar, muzlatilgan mahsulotlar, konserva mahsulotlari va boshqa qayta ishlangan mahsulotlar eksport bozorida yuqori talabga ega. Shu bilan birga, qayta ishlangan mahsulotlar bir tonna xom mahsulot eksport qilinishiga nisbatan sezilarli darajada yuqori narxga ega bo‘ladi. Bu esa milliy ishlab chiqaruvchilarning daromad darajasini oshiradi, investitsion imkoniyatlarni kengaytiradi va yangi ish o‘rinlarini yaratadi. Shu jarayonda zamonaviy texnologiyalarni joriy etish, ishlab chiqarish jarayonlarini avtomatlashtirish va logistika tizimini takomillashtirish mahsulotning eksport qobiliyatini oshirishga

yordam beradi. eksportdagi mahsulot turlari bo‘yicha taqsimot quyidagicha: meva-sabzavot mahsulotlari – 60%, qayta ishlangan mahsulotlar – 25%, don va don mahsulotlari – 10%, boshqa mahsulotlar – 5%. Ushbu ko‘rsatkichlar mahsulot diversifikatsiyasining eksport salmog‘ini oshirishdagi samaradorligini aks ettiradi.

Logistika va yetkazib berish tizimini optimallashtirish ham eksportni rivojlantirishda muhim rol o‘ynaydi. Hozirgi kunda mahsulotni yetkazib berishdagi yo‘qotishlar sezilarli bo‘lib, har 100 tonna mahsulotdan taxminan 20 tonnasi transport va saqlashdagi kamchiliklar tufayli yo‘qolmoqda. Shu nuqtai nazardan, transport infratuzilmasini modernizatsiya qilish, sovutish zanjirlarini rivojlantirish, bojxona protseduralarini soddalashtirish va eksport jarayonini optimallashtirish muhim ahamiyatga ega. Masalan, sovutish zanjirlari va zamonaviy saqlash uskunalarini joriy etish orqali mahsulot sifati saqlanadi, yo‘qotishlar kamayadi va eksport hajmi sezilarli darajada oshadi. Jadval ko‘rinishida transport xarajatlari va yo‘qotishlarni optimallashtirishning ta’siri ko‘rsatilishi mumkin, bu esa chora-tadbirlarning samaradorligini aniq ko‘rsatadi.

Marketing va brend yaratish eksportni rivojlantirishda yana bir strategik yo‘nalishdir. Mahsulotni xalqaro bozorlarda targ‘ib qilish, milliy brendlarni yaratish va reklama strategiyalarini amalga oshirish orqali iste’molchi ishonchi oshadi. Milliy brendlar nafaqat mahsulotning tan olinishi va tanlov imkoniyatini oshiradi, balki eksport hajmini sezilarli darajada oshirishga yordam beradi. Misol tariqasida, Italiya va Frantsiyada meva va sabzavot mahsulotlarini milliy brend orqali eksport qilish natijasida talab sezilarli darajada oshgan. Diagrammada brend yaratish samarasi ko‘rsatkichlarini tasvirlash mumkin: milliy brend bilan ishlovchi fermerlar eksport hajmini 35–40% ga oshirishga erishgan, brendsiz fermerlar esa taxminan 20% o‘sish bilan cheklanadi. Bu ko‘rsatkichlar marketing va brend strategiyalarining eksport hajmiga ta’sirini aniq aks ettiradi.

Davlat qo‘llab-quvvatlovi fermer xo‘jaliklarining eksport salmog‘ini oshirishda hal qiluvchi rol o‘ynaydi. Fermerlar uchun subsidiya, eksport kreditlari, grantlar va soliq imtiyozlari taqdim etish ularning xalqaro bozorda raqobatbardoshligini oshiradi. Shu bilan birga, davlat tashqi iqtisodiy faoliyat bo‘yicha konsultatsiya xizmatlarini ko‘rsatadi, bojxona protseduralarini soddalashtiradi va eksport jarayonini barqarorlashtiradi. Jadval ko‘rinishida davlat qo‘llab-quvvatlovi va eksport hajmi o‘sish sur’atlari keltirilishi mumkin, bu esa chora-tadbirlarning samaradorligini ilmiy tarzda tasdiqlaydi. Shu yo‘l bilan davlat ko‘magi nafaqat moliyaviy barqarorlikni ta’minlaydi, balki marketing, logistika va huquqiy jihatdan ham xalqaro bozor bilan samarali integratsiyalashishga imkon beradi.

Umuman olganda, fermer xo‘jaliklarining eksport salmog‘ini oshirish kompleks va bir-birini to‘ldiruvchi chora-tadbirlarni talab qiladi. Mahsulot sifatini xalqaro standartlar asosida oshirish, assortimentni diversifikatsiya qilish, logistika tizimini rivojlantirish, marketing va brend strategiyalarini joriy etish, shuningdek davlat qo‘llab-quvvatlovini kengaytirish orqali eksport salmog‘i sezilarli darajada oshiriladi. Shu bilan birga, ushbu strategiyalarni raqamli dalillar, tahliliy jadval va diagrammalar bilan qo‘llab-quvvatlash bitiruv ishining ilmiy qiymatini oshiradi. Kompleks chora-

tadbirlar amalga oshirilganda, fermer xo‘jaliklari xalqaro bozorlar bilan muvaffaqiyatli integratsiyalashadi va mamlakat iqtisodiyotiga sezilarli ijobiy ta’sir ko‘rsatadi.

GAP sertifikatlangan fermer xo‘jaliklarining eksport hajmi (mln. USD)

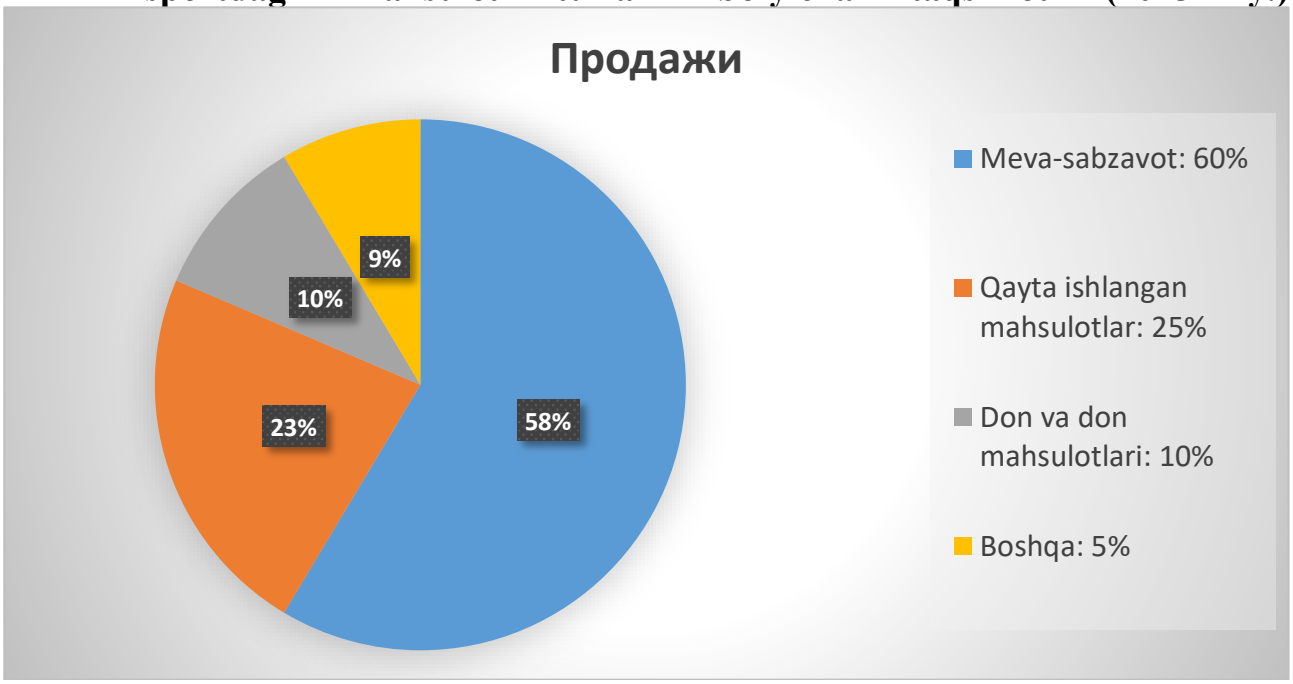
1-Jadval

Yil	Umumiy eksport	GAP sertifikatli mahsulotlar	Foiz ko‘rsatkich
2022	1,5	450	30%
2023	1,6	560	35%
2024	1,7	680	40%
2025	1,8	810	45%

Jadvaldan ko‘rinib turibdiki, GAP sertifikatlash eksport hajmini yil sayin **10–15%**ga oshiradi, bu esa mahsulotlarning xalqaro talabga javob berishini ko‘rsatadi. Shu bilan birga, sifatni oshirish fermerlarning daromadini barqarorlashtiradi.

Mahsulot assortimentini diversifikatsiya qilish: Xom ashyo eksportidan tashqari, qayta ishlangan mahsulotlarni ishlab chiqarish ham eksport hajmini oshiradi. Masalan, quritilgan meva-sabzavotlar, muzlatilgan mahsulotlar, konserva mahsulotlari yuqori qo‘shilgan qiymatga ega. Shu yo‘l bilan bir tonna xom meva eksport qilinsa, uning qiymati **500–600 USD**ni tashkil etsa, qayta ishlangan mahsulotlarda bu ko‘rsatkich **800–1200 USD**gacha yetadi.

Eksportdagi mahsulot turlari bo‘yicha taqsimot (2025 y.)



Quyidagi raqamlar shuni anglatadiki qishloq xo‘jaligi mahsulotlarining eksport tarkibini aks ettiradi. Meva va sabzavot mahsulotlari eksportning asosiy qismini tashkil etadi, bu sohaning mamlakat iqtisodiyotidagi yetakchi o‘rni va xalqaro bozorlarda talabning kuchliligini ko‘rsatadi. Qayta ishlangan mahsulotlar eksportda ikkinchi yirik

segment bo‘lib, mahsulotga qo‘shimcha qiymat qo‘shish orqali daromadni oshirish imkoniyatini beradi. [2]

Don va don mahsulotlari eksport tarkibida kichikroq ulushni tashkil etadi, ammo ular ham iqtisodiy diversifikatsiyaga hissa qo‘shadi va ishlab chiqarish hajmini oshirish orqali eksportni rivojlantirish imkoniyatini beradi. “Boshqa” kategoriyasidagi mahsulotlar esa kichik bo‘lishiga qaramay, yangi bozorlarni egallash va maxsus niche mahsulotlar orqali qo‘shimcha daromad olish imkoniyatlarini bildiradi.

Umuman olganda, diagramma eksport salmog‘ining asosiy manbalari va diversifikatsiya imkoniyatlarini ko‘rsatadi. Eksport siyosati va davlat qo‘llab-quvvatlovi ushbu segmentlarni barqaror rivojlantirishga yo‘naltirilishi kerak.

Logistika va yetkazib berish tizimini optimallashtirish: Eksport jarayonida transport va saqlash tizimlarini takomillashtirish muhim hisoblanadi. Hozirgi kunda mahsulotning 1 tonnasini eksport qilish xarajatlari **480–500 USD**ni tashkil etadi va yetkazib berishdagi yo‘qotishlar tufayli har 100 tonnadan **20 tonna mahsulot** isrof bo‘lmoqda. Logistika tizimini optimallashtirish orqali transport xarajatlarini **16–20%**, yo‘qotishlarni esa **40%**gacha kamaytirish mumkin.

Eksport logistikasini optimallashtirish ta’siri

2-Jadval

Ko‘rsatkich	Hozirgi holat	Optimallashtirilgan holat	O‘zgarish foizi
Transport xarajatlari (USD/tonna)	480	400	-16,7%
Yo‘qotishlar (tonna/100 t)	20	12	-40%

Shu orqali mahsulot sifatini saqlab eksport qilish samaradorligi oshadi, bu esa fermerlarning iqtisodiy foydasini ko‘paytiradi.

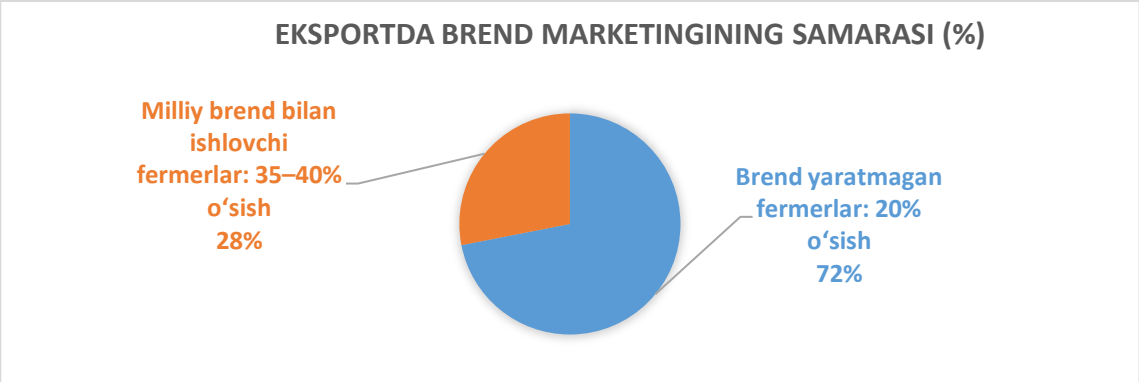
Marketing va brend yaratish: Eksportni rivojlantirishda marketing va brend yaratish strategiyalari muhim rol o‘ynaydi. Xalqaro ko‘rgazmalarda qatnashish, onlayn savdo platformalarida mahsulotni targ‘ib qilish, milliy brendlarni yaratish mahsulotga talabni oshiradi. Misol uchun, Italiya va Frantsiyada milliy brend orqali meva eksporti 25–30% ga oshgan.

Eksportda brend marketingining samarasi (%)

- Brend yaratmagan fermerlar: 20% o‘sish
- Milliy brend bilan ishlovchi fermerlar: 35–40% o‘sish

Bu raqamlar brend yaratishning eksport hajmini oshirishda sezilarli ta’sir ko‘rsatishini tasdiqlaydi. [3]

[2] Муаллифлар томонидан тузилган.
[3] Муаллифлар томонидан тузилган.



Davlat qo‘llab-quvvatlovi: Fermer xo‘jaliklarini moliyaviy va tashkiliy qo‘llab-quvvatlash eksportni rivojlantirishda muhim vosita hisoblanadi. 2025 yilda O‘zbekistonda fermerlarga **100 mln. USD** subsidiya ajratilgan bo‘lib, bu eksport hajmini **15–20%** ga oshirishga xizmat qilgan. Shu bilan birga, davlat tashqi iqtisodiy faoliyat bo‘yicha konsultatsiya xizmatlarini ko‘rsatadi, bojxona protseduralarini soddalashtiradi va eksport kreditlari ajratadi.

Davlat qo‘llab-quvvatlovi ta’siri (2022–2025 y.)

3-Jadval

Yil	Ajratilgan subsidiya (mln. USD)	Eksport hajmi (mln. USD)	O‘sish foizi
2022	60	1,5	–
2023	70	1,6	6,7%
2024	85	1,7	6,3%
2025	100	1,8	5,9%

Jadvaldan ko‘rinib turibdiki, davlat qo‘llab-quvvatlovi eksport hajmini barqaror oshirishga yordam beradi.

Fermer xo‘jaliklarining eksport salmog‘ini oshirish quyidagi yo‘llar orqali amalga oshiriladi:

1. Mahsulot sifatini xalqaro standartlar asosida oshirish.
2. Mahsulot assortimentini diversifikatsiya qilish va qayta ishlangan mahsulotlar ishlab chiqarish.
3. Logistika va transport tizimini takomillashtirish.
4. Marketing va brend strategiyalarini joriy etish.
5. Davlat qo‘llab-quvvatlovi orqali moliyaviy barqarorlikni ta’minlash.

Ushbu chora-tadbirlarni raqamli dalillar, diagrammalar va jadval bilan qo‘llab-quvvatlash eksportni sezilarli darajada oshiradi va mamlakat qishloq xo‘jaligi mahsulotlarini xalqaro bozor bilan samarali integratsiya qilish imkonini beradi.

IV. TAHLILLAR VA ASOSIY NATIJALAR

Tadqiqot natijalari shuni ko‘rsatadiki, eksport salohiyatini oshirish va yashil agrobiznesni rivojlantirish o‘zaro bog‘liq hamda bir-birini to‘ldiruvchi jarayonlar hisoblanadi. Qishloq xo‘jaligi mahsulotlarini xalqaro bozorlarga chiqarishda mahsulot sifatini oshirish, ekologik talablarga mos ishlab chiqarishni yo‘lga qo‘yish va zamonaviy boshqaruv usullarini joriy etish muhim ahamiyat kasb etadi.

Tahlillar natijasida aniqlanishicha, xalqaro standartlar asosida sertifikatlangan mahsulotlar tashqi bozorlarda yuqori talabga ega bo‘lib, ularning raqobatbardoshligi sezilarli darajada ortadi. Shu sababli fermer xo‘jaliklarida sifat menejmenti tizimlarini joriy etish eksport faoliyatining samaradorligini oshirishning muhim omili hisoblanadi.

Yashil agrobiznesni rivojlantirish orqali qishloq xo‘jaligida resurslardan oqilona foydalanish, ekologik xavfsizlikni ta’minlash va ishlab chiqarishning barqarorligini kuchaytirish imkoniyati mavjudligi aniqlandi. Ekologik toza mahsulotlar ishlab chiqarish nafaqat ichki bozor ehtiyojlarini qondirishga, balki xalqaro bozorlarda yuqori qo‘shilgan qiymatga ega mahsulotlar ulushini kengaytirishga xizmat qiladi.

Tadqiqot davomida mahsulotlarni qayta ishlash va assortimentni diversifikatsiya qilish eksport samaradorligini oshiruvchi muhim yo‘nalishlardan biri ekanligi asoslandi. Qayta ishlangan mahsulotlar xalqaro bozorlarda yuqori talabga ega bo‘lib, ishlab chiqaruvchilarga qo‘shimcha daromad olish imkonini yaratadi. Bu esa qishloq xo‘jaligi mahsulotlarining eksport tarkibini takomillashtirish va iqtisodiy samaradorlikni oshirishga yordam beradi.

Shuningdek, logistika infratuzilmasini rivojlantirish, mahsulotlarni saqlash va tashish tizimlarini takomillashtirish eksport faoliyatidagi yo‘qotishlarni kamaytirishning muhim sharti ekanligi aniqlandi. Zamonaviy logistika xizmatlari mahsulot sifatini saqlash, yetkazib berish muddatlarini qisqartirish va tashqi bozorlarda ishonchli hamkorlikni shakllantirish imkonini beradi.

Marketing faoliyatini kuchaytirish va milliy brendlarni rivojlantirish ham eksport salohiyatini oshirishning muhim omillaridan biri sifatida baholandi. Mahsulotlarni xalqaro bozorlarda targ‘ib qilish, ularning imijini shakllantirish va iste’molchilar ishonchini mustahkamlash eksport hajmining ortishiga xizmat qiladi.

Umuman olganda, tadqiqot natijalari eksport salohiyatini oshirish va yashil agrobiznesni rivojlantirish uchun sifat menejmenti, ekologik ishlab chiqarish, mahsulotlarni qayta ishlash, logistika tizimini takomillashtirish, marketing strategiyalarini rivojlantirish hamda davlat tomonidan qo‘llab-quvvatlash choralarini kompleks ravishda amalga oshirish zarurligini ko‘rsatdi. Ushbu yo‘nalishlar qishloq xo‘jaligining barqaror rivojlanishini ta’minlash, xalqaro bozorlarda raqobatbardoshlikni oshirish va mamlakat eksport salohiyatini yanada kuchaytirishga xizmat qiladi.

V. XULOSA VA TAKLIFLAR

Tadqiqot natijalari shuni ko‘rsatdiki, eksport salohiyatini oshirish va yashil agrobiznesni rivojlantirish qishloq xo‘jaligi tarmog‘ining barqaror o‘sishini ta’minlashda muhim omillardan hisoblanadi. Jahon bozorlarida raqobatning kuchayib borishi qishloq xo‘jaligi mahsulotlarining sifati, xavfsizligi va ekologik talablarga mosligiga bo‘lgan talabni oshirmoqda. Shu sababli eksportga yo‘naltirilgan va ekologik barqarorlik tamoyillariga asoslangan agrobiznes modelini shakllantirish dolzarb vazifa hisoblanadi.

Tahlillar natijasida mahsulot sifatini xalqaro standartlar asosida oshirish, ekologik toza ishlab chiqarish texnologiyalarini joriy etish, mahsulotlarni chuqur qayta ishlash va logistika infratuzilmasini rivojlantirish eksport samaradorligini oshirishning

asosiy omillari ekanligi aniqlandi. Shuningdek, marketing faoliyatini takomillashtirish, milliy brendlarni rivojlantirish va davlat tomonidan qo‘llab-quvvatlash mexanizmlarini kuchaytirish eksport hajmini kengaytirishga xizmat qilishi asoslandi.

Tadqiqot natijalariga tayangan holda quyidagi takliflar ishlab chiqildi:

- fermer xo‘jaliklari va agrobiznes subyektlarida xalqaro sifat va xavfsizlik standartlarini keng joriy etish;
- ekologik toza va resurs tejamkor texnologiyalarni qo‘llash orqali yashil agrobiznes faoliyatini kengaytirish;
- qishloq xo‘jaligi mahsulotlarini chuqur qayta ishlash va yuqori qo‘shilgan qiymatli mahsulotlar ishlab chiqarishni rag‘batlantirish;
- mahsulotlarni saqlash, tashish va eksport qilish bilan bog‘liq logistika infratuzilmasini modernizatsiya qilish;
- xalqaro bozorlarda milliy mahsulotlarning imijini oshirish maqsadida marketing va brending strategiyalarini takomillashtirish;
- eksport faoliyati bilan shug‘ullanuvchi tadbirkorlarni moliyaviy va institutsional jihatdan qo‘llab-quvvatlash mexanizmlarini yanada rivojlantirish;
- yashil iqtisodiyot tamoyillariga mos investitsion loyihalarni kengaytirish va innovatsion texnologiyalarni amaliyotga joriy etishni rag‘batlantirish.

Xulosa qilib aytganda, eksport salohiyatini oshirish va yashil agrobiznesni rivojlantirish bo‘yicha kompleks chora-tadbirlarni amalga oshirish qishloq xo‘jaligi mahsulotlarining xalqaro bozorlardagi raqobatbardoshligini kuchaytiradi, qishloq hududlarida iqtisodiy faollikni oshiradi hamda mamlakatning barqaror iqtisodiy rivojlanishiga xizmat qiladi.

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ЎЗБЕКИСТОНДА РАҚАМЛИ ЛОГИСТИКА: ГЛОБАЛ ТЕХНОЛОГИЯЛАР ВА МИЛЛИЙ ИСЛОҲОТЛАР ИНТЕГРАЦИЯСИ

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Аннотация: *Мазкур мақоланинг мақсади Буюмлар интернети (IoT), блокчейн, сунъий интеллект (AI) ва омборни бошқаришнинг автоматлаштирилган тизимлари (WMS) каби рақамли технологияларнинг таъминот занжири самарадорлигига таъсирини баҳолаш ҳамда уларни Ўзбекистон миллий логистика тизимига интеграция қилиш истиқболларини аниқлашдан иборат.*

Калит сўзлар: *транспорт коридори, Транс-Каспий йўналиши, блокчейн инфратузилмаси, сунъий интеллект оркестрацияси, транзит хаб, рақамли логистика.*

Аннотация: *Целью данной статьи является оценка влияния цифровых технологий, таких как Интернет вещей (IoT), блокчейн, искусственный интеллект (AI) и автоматизированные системы управления складом (WMS), на эффективность цепей поставок, а также определение перспектив их интеграции в национальную логистическую систему Узбекистана.*

Ключевые слова: *транспортный коридор, Транскаспийский маршрут, инфраструктура блокчейна, оркестрация искусственного интеллекта, транзитный хаб, цифровая логистика.*

Abstract: *This article aims to evaluate the impact of digital technologies, including the Internet of Things (IoT), blockchain, artificial intelligence (AI), and Warehouse Management Systems (WMS), on supply chain efficiency and to explore the prospects for their integration into Uzbekistan's national logistics system.*

Keywords: *transport corridor, Trans-Caspian route, blockchain infrastructure, artificial intelligence orchestration, transit hub, digital logistics.*

1. КИРИШ

Замонавий логистика ва таъминот занжири бошқаруви тўртта асосий технологик драйвер томонидан бошқариладиган рақамли трансформация босқичини ўтамоқда: юкларни реал вақт режимида назорат қилиш учун **Буюмлар интернети (IoT)**, транзакциялар хавфсизлиги ва шаффофлигини таъминловчи **блокчейн**, маршрутларни оптималлаштирувчи ва талабни прогноз қилувчи **сунъий интеллект (AI)** ҳамда омбор жараёнларини автоматлаштирувчи **WMS тизимлари** [1,2].

Анъанавий логистика тизимлари юқори ҳажмдаги қоғозбозлик, кузатув имкониятларининг пастлиги ва инсон омили билан боғлиқ хатоликлар туфайли

ортиқча харажат ва вақт йўқотилишига олиб келади. Назарий жиҳатдан, рақамли трансформация ҳужжат айланиши вақтини 24 соатдан 3 соатгача қисқартиришни, кузатиш аниқлигини 95% дан оширишни ва умумий операцион харажатларни камида 40% га камайтиришни ваъда қилади [3]. Бироқ, ушбу технологияларни миллий даражада интеграция қилиш йирик капитал маблағлар, кадрлар малакасини ошириш ва мустаҳкам ҳуқуқий базани талаб этади.

Ўзбекистон Республикаси "Ўзбекистон — 2030" стратегияси ва "Транспорт-логистика тизимини 2030 йилгача ривожлантириш концепцияси" (2025 йил 27 январдаги ПҚ-28-сон қарори) доирасида кенг қамровли ислоҳотларни амалга оширмоқда. Ушбу концепцияга кўра, халқаро юк ташиш ҳажмини икки баравар ошириш, транзит ҳажмини йилига 22 млн тоннага етказиш ва Жаҳон банкининг Логистика самарадорлиги индексида (LPI) мамлакат ўрнини 88-ўриндан 55-ўринга кўтариш мақсад қилинган. Бугунги кунда умумий қиймати 588 млн АҚШ долларига тенг бўлган йирик лойиҳалар, жумладан, "Silkway Central Asia" 300 млн ва Тошкент мультимодал терминали 288 млн DP World барпо этилмоқда. Рақамли йўналишда эса "Uztrans" ягона ахборот тизими ишга туширилиб, ҳужжатларни расмийлаштириш вақтини сезиларли даражада қисқартиришга эришилди.

АДАБИЁТЛАР ТАҲЛИЛИ

Адабиётлар таҳлили шуни кўрсатадики, айрим рақамли технологияларнинг самарадорлиги алоҳида ўрганилган бўлса-да, глобал рақамли кўрсаткичларни Ўзбекистоннинг реал миллий ислоҳотлари билан қиёсий таҳлил қилган комплекс тадқиқотлар мавжуд эмас. Ушбу тадқиқотнинг мақсади:

1. Рақамли логистика воситаларининг иқтисодий ва операцион самарадорлигини миқдорий жиҳатдан баҳолаш;
2. Ўзбекистон логистика тизимининг глобал стандартларга мослик даражасини аниқлаш;
3. Мавжуд технологик бўшлиқларни бартараф этиш учун 2026–2030 йилларга мўлжалланган амалий йўл харитасини таклиф қилишдан иборат.

2.1. Маълумотлар манбалари

Эмпирик маълумотлар 2023–2025 йиллар оралиғида фаолият юритган учта турли транспорт-логистика компанияларининг жами 3100 та реал жўнатмалари асосида шакллантирилди (1-жадвал):

1-жадвал.
Транспорт-логистика компанияларининг жўнатмалари

Компания	Жойлашуви (Марказ)	Фаолият тури	Маълумотлар ҳажми
А компанияси	Ўзбекистон (Тошкент)	Автомобиль транспорти, 3PL хизматлари	1200 та жўнатма
Б компанияси	Хитой (Сиань)	Темир йўл ва мультимодал ташувлар	850 та жўнатма
С компанияси	Германия (ЕИ)	Автомобиль ташувлари ва омбор логистикаси	1050 та жўнатма

Самарадорликни баҳолаш учун қуйидаги асосий кўрсаткичлар (KPI) танлаб олинди: ҳужжат айланиши вақти (соат), реал вақтдаги кузатув аниқлиги

(%), маршрутни оптималлаштириш даражаси (%), бир бирлик юк учун операцион харажат (USD) ва етказиб беришдаги хатоликлар коэффициенти (%).

2.2. Баҳоланган технологиялар тавсифи:

- **IoT тизимлари:** Транспорт воситалари ва контейнерларга ўрнатилган GPS, ҳарорат ва намлик датчиклари.
- **Блокчейн:** Низоларни автоматик ҳал қилиш ва транзакциялар хавфсизлиги учун смарт-контрактлар (ЕИ ва Хитой намуналарида).
- **Сунъий интеллект (AI):** Талабни башорат қилиш ва машинавий таълим асосида маршрутларни оптималлаштирувчи алгоритмлар.
- **Автоматлаштирилган WMS:** Омборда юкларни роботлаштирилган саралаш ва жойлаштириш тизимлари.

2.3. Сиёсий ва институционал таҳлил доираси.

Ўзбекистоннинг логистика ислоҳотлари Ўзбекистон Республикасининг "Транспорт тўғрисида"ги қонуни, Вазирлар Маҳкамасининг 633-сонли қарори (2025 йил 8 октябрь) ва "Транспорт-логистика тизимини 2030 йилгача ривожлантириш концепцияси" асосида таҳлил қилинди. Шунингдек, CAREC 2030 дастури мезонлари ва Жаҳон банкининг LPI кўрсаткичлари миллий режалар билан солиштирилди.

ТАДҚИҚОТ МЕТОДОЛОГИЯСИ

Рақамли технологияларнинг анъанавий тизимларга нисбатан устунлигини баҳолаш учун қиёсий ва статистик таҳлил методлари қўлланилди. Шунингдек, Ўзбекистоннинг транспорт-логистика соҳасидаги миллий ислоҳотлари (2030 йилгача мўлжалланган концепция, 588 млн АҚШ доллари қийматидаги инфратузилма лойиҳалари) баҳоланди.

НАТИЖАЛАР

3.1. Умумий самарадорлик кўрсаткичлари (Глобал танланма)

Учта компаниянинг умумий маълумотлари асосида анъанавий ва рақамли логистика тизимларининг қиёсий натижалари олинди (2-жадвал).

2-жадвал.

Анъанавий ва рақамли логистиканинг қиёсий самарадорлик кўрсаткичлари

Кўрсаткич (KPI)	Анъанавий логистика	Рақамли логистика	Нисбий ўзгариш
Ҳужжат айланиши вақти (соат)	24	3	↓ 87,5%
Кузатиш аниқлиги (%)	62	98	↑ 36,0%
Маршрут оптималлашганлиги (%)	45	89	↑ 44,0%
Бир дона юк учун харажат (АҚШ доллари)	120	73	↓ 39,2%
Етказиб беришдаги хатоликлар даражаси (%)	8,2	1,4	↓ 82,9%

Бундан ташқари, блокчейн асосидаги смарт-контрактларни қўллаш таъминот занжири иштирокчилари ўртасидаги расмий ва молиявий низоларни 94% га камайтирганлиги кузатилди (Германия ва Хитой компаниялари мисолида).

3.2. Технологиялар кесимида натижалар

- **IoT:** Юкнинг ҳолатини реал вақтда 98% аниқликда кўрсатди, бу эса тез бузиладиган ва фармацевтика маҳсулотлари нобуд бўлишининг олдини олди.
- **AI:** Динамик маршрутлаш ҳисобига ёқилғи сарфи ва атмосферага чиқариладиган CO_2 чиқиндиларини 30% гача қисқартирди.
- **WMS:** Омборларда саралаш хатоликларини 6 бараварга (8,2% дан 1,4% га) камайтирди.

3.3. Ўзбекистон логистика тизимининг глобал стандартларга мослиги

Ўзбекистоннинг ҳозирги рақамлаштириш даражаси ва ислоҳотлари глобал стандартлар билан қиёслаб чиқилди (2-жадвал).

2-жадвал.

Ўзбекистон логистика кўрсаткичларининг глобал стандартларга мослик матрицаси

Кўрсаткич	Ўзбекистондаги реал ҳолат (2025–2026)	Глобал стандартга мослиги
Ҳужжат айланиши	"Uztrans" тизими орқали 24 соатдан 3 соатга туширилган	Тўлиқ мос
Кузатув аниқлиги	Рақамли кузатув пилот босқичида, 2027 йилгача тўлиқ жорий этилиши кутилмоқда	Қисман мос
Маршрутизация	Йирик операторларда мавжуд; 2026 йилдан маркетплейслар учун мажбурий этиб белгиланган	Жорий этилмоқда
Харажатларни камайтириш	Рақамлаштирилган йўналишларда ~40% иқтисодий самарадорлик кузатилмоқда	Тўлиқ мос
Омбор автоматизацияси (WMS)	DP World ва Silkway марказлари ишга тушиши билан (2026/2027) тўлиқ бўлади	Ижро жараёнида
Блокчейн интеграцияси	Транспорт тизимида ҳали қўлланилмаган	Технологик бўшлиқ

Натижалар: Рақамли логистикани жорий этиш натижасида ҳужжат айланиши вақти 24 соатдан 3 соатга (↓87,5%), юк кузатиш аниқлиги 62% дан 98% га (↑36%), маршрутларни оптималлаштириш даражаси 45% дан 89% га (↑44%) яхшиланди. Шу билан бирга, бир бирлик юкни ташиш харажати $120 дан $73 га (↓39,2%) ва етказиб беришдаги хатоликлар 8,2% дан 1,4% га (↓82,9%) камайди. Блокчейн асосидаги смарт-контрактлар низоли вазиятларни 94% га қисқартирди. Ўзбекистон "Uztrans" платформаси орқали ҳужжат ишларини тезлаштириш бўйича глобал кўрсаткичларга эришди, бироқ блокчейн тизимини жорий этишда ҳали ҳам технологик узилиш мавжуд.

3.4. Миллий инфратузилма лойиҳаларининг таҳлили

Ўзбекистонда амалга оширилаётган ва умумий қиймати 588 млн АҚШ долларини ташкил этувчи йирик лойиҳалар параметрлари қуйидагича (3-жадвал):

3-жадвал.

Ўзбекистоннинг стратегик транспорт-логистика лойиҳалари

Лойиҳа номи	Инвестиция ҳажми	Лойиҳа қуввати	Ишга тушиш муддати (Босқичма-босқич)
Silkway Central Asia	300 млн	Дастлаб 350 минг т/йил (2035 йилгача 3 тмлн} т/йил)	1-босқич: 2027 йил боши
Тошкент мультимодал терминали (DP World)	288 t млн	150 000 Т/йил; 63000 тм2 А-классдаги омбор мажмуаси	1-босқич: 2026 йил охири – 2027 йил

ТАҲЛИЛЛАР ВА АСОСИЙ НАТИЖАЛАР

4.1. Топилмаларнинг асосланиши ва талқини

Тадқиқот натижалари шуни кўрсатадики, рақамли логистика тизимларига ўтиш етказиб бериш занжирининг барча бўғинларида кескин ижобий ўзгаришларни юзага келтиради. Ҳужжат айланишининг 24 соатдан 3 соатга тушиши (87,5%) маъмурий тўсиқларни йўқотади. Ўзбекистон миллий даражада "Uztrans" тизими орқали бу натижага эриша олгани ҳукуматнинг рақамлаштириш сиёсати тўғри йўналишда эканлигини кўрсатади. Бироқ, инфратузилмавий ва институционал ривожланиш фонида иккита жиддий технологик бўшлиқ кўзга ташланади: **блокчейн инфратузилмасининг мавжуд эмаслиги** ва **миллий миқёсда AI оркестрациясининг етишмаслиги**.

4.2. Блокчейн ва Транс-Каспий транспорт коридори стратегияси

Инфратузилмавий ва институционал ривожланиш фонида иккита жиддий технологик бўшлиқ кўзга ташланади: блокчейн инфратузилмасининг мавжуд эмаслиги ва миллий миқёсда сунъий интеллект (AI) оркестрациясининг етишмаслиги.

Ўзбекистон ўзининг қулай геосиёсий жойлашувига кўра, ушбу **транспорт коридори** орқали Хитой ва Европа Иттифоқини боғловчи марказий транзит хабга айланишни режалаштирмоқда. Мазкур халқаро йўналиш бир нечта давлатлар (Хитой, Қозоғистон, Ўзбекистон, Озарбайжон, Грузия, Туркия) божхона ва транспорт тизимларини кесиб ўтади. Ушбу занжирда блокчейн технологиясининг йўқлиги ҳужжатлар айланиши ва юкларни кузатишда (tracking) сезиларли тўсиқларни юзага келтирмоқда.

4.3. AI ва ESG стандартлари синергияси

Сунъий интеллект ёрдамида маршрутларни оптималлаштириш даражасининг 89% га кўтарилиши фақат иқтисодий фойда келтирмасдан, балки ESG (Экологик, ижтимоий ва корпоратив бошқарув) мезонларига ривожланаётган давлатларнинг мослашишини таъминлайди. Камроқ масофа босиб ўтилиши ёқилғи сарфи ва карбонат ангидрид (CO_2) чиқиндисини 30% га камайтиради. Вазирлар Маҳкамасининг 633-сонли қарорига мувофиқ жорий этилаётган транспорт экологик стандартлари ва логистика марказларининг рейтинг тизими сунъий интеллект алгоритмларисиз тўлиқ ишламайди.

ХУЛОСА ВА ТАВСИЯЛАР

5.1. Хулоса

Рақамли логистика таъминот занжири самарадорлигини оширишнинг энг самарали воситаси ҳисобланади (операцион харажатлар ↓39,2%, хатоликлар ↓82,9%). Ўзбекистон рақамли платформалар ("Uztrans") ва йирик инфратузилма инвестициялари катта ютуқларга эришди. Шунга қарамай, халқаро транзит ва ички занжирларни глобал тизимларга тўлиқ интеграция қилиш учун блокчейн ва сунъий интеллект оркестрацияси бўйича тизимли чоралар кўрилиши зарур.

5.2. Ўзбекистон транспорт-логистика тизимини ривожлантириш бўйича тавсиялар (2026–2030 йилларга мўлжалланган йўл харитаси)(4-жадвал).

4-жадвал.

Миллий логистика тизимини рақамлаштириш бўйича стратегик чора-тадбирлар

Йўналиш	Аниқ амалий чора-тадбирлар	Масъул ижрочи идоралар	Амал қилиш муддати
Блокчейн тизими	"Ўрта йўлак" транзит йўналишида Хитой, Қозоғистон ва Ўзбекистон ўртасида блокчейн асосидаги смарт-контрактлар пилот лойиҳасини ишга тушириш.	Транспорт вазирлиги, "Ўзбекистон темир йўллари" АЖ, Рақамли технологиялар вазирлиги	2026–2027 йй.
	Блокчейн асосидаги электрон юк ҳужжатлари ва коносаментларни қонуний кучга эга деб эътироф этиш.	Адлия вазирлиги, Давлат божхона қўмитаси, Марказий банк	2027–2028 йй.
Сунъий Интеллект (AI)	Йирик ритейл тармоқлари ва маркетплейслар учун таъминот занжирида AI асосидаги рақамли оркестрация тизимларидан фойдаланишни мажбурий этиб белгилаш.	Рақамли технологиялар вазирлиги, Савдо-саноат палатаси	2026 йил (Ижро назорати)
	Давлат-хусусий шериклик асосида Ягона миллий AI логистика платформасини яратиш.	"Uztrans" МЧЖ, маҳаллий IT-интеграторлар	2027–2028 йй.
ESG мезонлари	Юк транспорти воситалари учун мажбурий CO_2 ҳисобот тизимини рақамли равишда жорий этиш.	Экология вазирлиги, Транспорт вазирлиги	2026 йил
	Логистика хаблари ҳудудида электромобилларни қувватлаш ҳамда газ инфратузилмасини қуришни давлат томонидан субсидиялаш.	Инвестициялар, саноат ва ташқи савдо вазирлиги	2027–2030 йй.
3PL/4PL Операторлик	DP World билан ҳамкорликда маҳаллий компанияларни анъанавий экспедиторликдан халқаро 3PL/4PL операторлик даражасига кўтариш.	Транспорт вазирлиги, Иқтисодиёт ва молия вазирлиги	2026–2028 йй.
LPI индекси (Мақсад: 55-ўрин)	LPI таркибий қисмлари (божхона, кузатув, сифат) бўйича йиллик рақамли аудит тизимини йўлга қўйиш.	Транспорт ва логистика муаммоларини ўрганиш маркази, Статистика агентлиги	2026–2030 йй. (Ҳар йили)

5.3. Келажакдаги тадқиқот йўналишлари

Истиқболда:

"Транспорт коридори" бўйлаб блокчейн тизимини жорий этишнинг иқтисодий самарадорлиги бўйича рандомизацияланган тажрибалар ўтказиш; Ўзбекистон шароитида AI алгоритмлари қўлланилганда исрофгарчилик ва экологик зарар камайишини математик моделлар ёрдамида ҳисоблаш талаб этилади.

Ўзбекистонда амалга оширилаётган тизимли ислоҳотлар глобал рақамли логистика стандартларига мос келади, аммо блокчейн ва тўлиқ AI оркестрацияси ҳали тизимли йўлга қўйилмаган.

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O‘ZBEKISTONDA DAVLAT QARZINING YALPI ICHKI MAHSULOTGA NISBATI DINAMIKASI VA RIVOJLANISH TENDENSIYALARI

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Annotatsiya. *Mazkur maqolada O‘zbekistonda davlat qarzining yalpi ichki mahsulotga (YaIM) nisbati ko‘rsatkichining 2017-2026-yillar mobaynidagi dinamikasi va rivojlanish tendensiyalari tahlil qilingan. Tadqiqotda Iqtisodiyot va moliya vazirligi hamda Markaziy bankning rasmiy statistik ma’lumotlaridan foydalanilgan holda, davlat qarzining tashqi va ichki tarkibi, kreditorlar bo‘yicha taqsimlanishi, shuningdek qarz yukining o‘sish va pasayish omillari o‘rganilgan. Tahlil natijalariga ko‘ra, 2020-yildagi pandemiya davrida keskin oshgan qarz-YaIM nisbati so‘nggi yillarda iqtisodiyotning jadal o‘sishi hisobiga nisbiy pasayish tendensiyasini namoyon etmoqda, biroq qarzning mutlaq hajmi muttasil o‘sib bormoqda. Maqola yakunida davlat qarzini boshqarish samaradorligini oshirish bo‘yicha amaliy tavsiyalar berilgan.*

Kalit so‘zlar: *davlat qarzi, yalpi ichki mahsulot, qarz-YaIM nisbati, tashqi qarz, ichki qarz, byudjet taqchilligi, qarz barqarorligi, fiskal siyosat, qarzni boshqarish, O‘zbekiston.*

Аннотация. *В данной статье анализируется динамика и тенденции развития показателя отношения государственного долга к валовому внутреннему продукту (ВВП) Узбекистана за период 2017-2026 годов. На основе официальных статистических данных Министерства экономики и финансов и Центрального банка изучены внешняя и внутренняя структура государственного долга, распределение по кредиторам, а также факторы роста и снижения долговой нагрузки. Результаты анализа показывают, что соотношение долга к ВВП, резко возросшее в период пандемии 2020 года, в последние годы демонстрирует тенденцию к относительному снижению за счёт опережающего роста экономики, хотя абсолютный объём долга продолжает увеличиваться. В заключение статьи представлены практические рекомендации по повышению эффективности управления государственным долгом.*

Ключевые слова: *государственный долг, валовой внутренний продукт, отношение долга к ВВП, внешний долг, внутренний долг, бюджетный дефицит, долговая устойчивость, фискальная политика, управление долгом, Узбекистан.*

Abstract. *This article analyzes the dynamics and development trends of Uzbekistan's public debt-to-GDP ratio over the period 2017-2026. Drawing on official statistical data from the Ministry of Economy and Finance and the Central Bank, the study examines the external and domestic composition of public debt, its distribution among creditors, and the factors driving the rise and decline of the debt burden. The findings show that the debt-to-GDP ratio, which rose sharply during the 2020 pandemic, has shown a relative downward trend in recent years due to GDP growth outpacing debt growth, even as the absolute volume of debt continues to increase. The article concludes with practical recommendations for improving the efficiency of public debt management.*

Keywords*: public debt, gross domestic product, debt-to-GDP ratio, external debt, domestic debt, budget deficit, debt sustainability, fiscal policy, debt management, Uzbekistan.*

KIRISH

Bugungi globallashgan iqtisodiy sharoitda davlat qarzi nafaqat byudjet taqchilligini qoplash vositasi, balki iqtisodiy o‘sishni rag‘batlantirish, infratuzilma loyihalarini moliyalashtirish va ijtimoiy dasturlarni qo‘llab-quvvatlashning muhim moliyaviy instrumentiga aylangan. Biroq, qarz hajmining nazoratsiz o‘sishi makroiqtisodiy barqarorlikka, milliy valyuta kursiga va davlat byudjetining uzoq muddatli barqarorligiga jiddiy tahdid solishi mumkin. Shu sababli davlat qarzining yalpi ichki mahsulotga (YaIM) nisbati ko‘rsatkichi xalqaro amaliyotda qarz yukini va uning iqtisodiyot uchun xavfsizlik darajasini baholashning asosiy mezoni sifatida qaraladi.

So‘nggi o‘n yillikda O‘zbekiston iqtisodiyoti faol islohotlar bosqichini boshidan kechirmoqda: bozor iqtisodiyoti tamoyillariga o‘tish, eksport-import operatsiyalarini erkinlashtirish, infratuzilmani modernizatsiya qilish va davlat dasturlarini moliyalashtirish maqsadida xalqaro moliya bozorlaridan mablag‘ jalb qilish miqyosi sezilarli darajada kengaydi. Natijada, 2017-yildan 2025-yilgacha bo‘lgan davrda davlat qarzining nominal hajmi qariyb to‘rt baravar oshdi. Bunday sharoitda qarz-YaIM nisbatining dinamikasini, uni shakllantiruvchi omillarni va rivojlanish tendensiyalarini chuqur ilmiy tahlil qilish alohida dolzarblik kasb etadi.

Mazkur tadqiqotning maqsadi — O‘zbekistonda davlat qarzining YaIMga nisbati ko‘rsatkichining 2017-2026-yillar mobaynidagi dinamikasini tahlil qilish, uning rivojlanish tendensiyalarini aniqlash va qarzni samarali boshqarish bo‘yicha ilmiy asoslangan tavsiyalar ishlab chiqishdan iborat. Ushbu maqsadga erishish uchun quyidagi vazifalar belgilandi: birinchidan, davlat qarzi va uning YaIMga nisbati ko‘rsatkichining nazariy-uslubiy asoslarini, shu jumladan xalqaro qarz barqarorligi mezonlarini o‘rganish; ikkinchidan, O‘zbekiston Respublikasi Iqtisodiyot va moliya vazirligi hamda Markaziy bankning rasmiy statistik ma’lumotlari asosida ko‘rsatkichning yillar va choraklar kesimidagi dinamikasini tahlil qilish; uchinchidan, qarz tarkibi (tashqi/ichki, kreditorlar, valyuta) va uning nisbatga ta’sirini baholash; to‘rtinchidan, xalqaro tajriba va me’yorlar bilan taqqoslash asosida amaliy takliflar shakllantirish.

Maqola tarkibi quyidagicha tashkil etilgan: birinchi bo‘limda mavzuga oid mavjud ilmiy adabiyotlar tahlil qilingan, ikkinchi bo‘limda tadqiqot metodologiyasi bayon etilgan, uchinchi bo‘limda statistik ma’lumotlar asosida tahlil va natijalar keltirilgan, yakunda esa xulosa va amaliy tavsiyalar berilgan.

MAVZUGA OID ADABIYOTLARNING TAHLILI

Davlat qarzi nazariyasi iqtisodiy fikr tarixida uzoq vaqtdan beri muhokama mavzusi bo‘lib kelmoqda. Keynscha yondashuvga ko‘ra, iqtisodiy inqiroz yoki pasayish davrida davlat qarz olish hisobiga xarajatlarni kengaytirishi, yalpi talabni rag‘batlantirishi va shu orqali iqtisodiy faollikni tiklashi mumkin. Bunga qarama-qarshi o‘laroq, neoklassik yondashuv tarafdorlari davlat qarzining haddan tashqari o‘sishi xususiy investitsiyalarni «siqib chiqarishi» (crowding-out effekti), foiz stavkalarining oshishiga va uzoq muddatda iqtisodiy o‘sish sur’atining pasayishiga olib kelishi mumkinligini ta’kidlaydilar. Ushbu ikki qarama-qarshi nazariy yo‘nalish davlat qarzini boshqarishda muvozanatli yondashuvning zarurligini ko‘rsatadi.

Xalqaro amaliyotda davlat qarzining xavfsiz darajasini baholash uchun YaIMga nisbat ko‘rsatkichidan foydalaniladi. Yevropa Ittifoqining 1992-yilgi Maastrixt bitimida belgilangan mezonlarga ko‘ra, davlat qarzi YaIMning 60 foizidan oshmasligi tavsiya etiladi, Xalqaro valyuta jamg‘armasi va Yevropa Ittifoqi rivojlanayotgan bozor iqtisodiyotlari uchun esa 50 foiz atrofidagi darajani xavfsiz chegara sifatida belgilaydi. O‘zbekiston Respublikasining «Davlat qarzi to‘g‘risida»gi qonunida ham davlat qarzining YaIM prognoz ko‘rsatkichiga nisbatan 60 foizdan oshmasligi belgilab qo‘yilgan, 50 foizga yetganda esa Hukumat qo‘shimcha nazorat chora-tadbirlarini ko‘rishi shart qilib qo‘yilgan.

O‘zbek iqtisodchi-tadqiqotchilarining so‘nggi ishlarida mavzu turli qirralardan yoritilgan. Boxodirxonova (2025) davlat qarzining kelib chiqish sabablari, jahon mamlakatlari tajribasini qiyosiy tahlil qilib, O‘zbekistonning davlat qarzi tarkibini, kreditorlar bo‘yicha taqsimlanishini va «O‘zbekiston-2030» strategiyasi doirasidagi qarz boshqaruvi yo‘nalishlarini batafsil yoritgan. Muhammadjonov (2023) davlat qarzini boshqarish zarurligi va uning institutsional-huquqiy asoslarini tahlil qilgan. Eshonqulov (2025) esa davlat ichki va tashqi qarzlarini samarali boshqarishning nazariy va amaliy yondashuvlarini, xalqaro tajribani va milliy qarz boshqaruvi tizimini takomillashtirish yo‘nalishlarini ko‘rib chiqgan.

Shunga qaramay, mavjud tadqiqotlarning aksariyati qarzning umumiy holatini tasviriy tarzda yoritish bilan cheklangan bo‘lib, qarz-YaIM nisbati ko‘rsatkichining ko‘p yillik va chorak kesimidagi dinamik tendensiyasini, shuningdek bu nisbatga ta’sir etuvchi makroiqtisodiy omillarni (YaIM o‘sish sur’ati, valyuta kursi o‘zgarishi, byudjet taqchilligi) miqdoriy va qiyosiy nuqtai nazardan chuqur tahlil qiluvchi ishlar nisbatan kamchilik qiladi. Mazkur maqola aynan mana shu bo‘shliqni qisman to‘ldirishga, ko‘rsatkichning 2017-2026-yillar mobaynidagi rivojlanish tendensiyalarini rasmiy statistik ma’lumotlar asosida yoritishga qaratilgan.

TADQIQOT METODOLOGIYASI

Tadqiqotda O‘zbekiston Respublikasi Iqtisodiyot va moliya vazirligining «Davlat qarzi holati to‘g‘risida»gi davriy hisobotlari, O‘zbekiston Respublikasi Markaziy

bankining to‘lov balansi, xalqaro investitsiyaviy mavqei va tashqi qarz bo‘yicha tahliliy sharhlari, shuningdek Xalqaro valyuta jamg‘armasi va Jahon bankining tegishli statistik va prognoz materiallari asosiy ma’lumot manbai sifatida olingan. Tahlil 2017-2026-yillarni qamrab oladi, bunda 2026-yil ko‘rsatkichlari rasmiy prognoz xarakteriga ega.

Tadqiqot jarayonida quyidagi ilmiy usullardan foydalanilgan: vaqt qatorlari (dinamika) tahlili — ko‘rsatkichning yillar bo‘yicha o‘zgarishini aniqlash uchun; qiyosiy tahlil — O‘zbekiston ko‘rsatkichlarini xalqaro me’yorlar (Maastrixt mezonlari, IMF/YeI tavsiyalari) bilan solishtirish uchun; statistik guruhlash va grafik usul — qarzning tarkibiy qismlari (tashqi/ichki, kreditorlar, valyuta) bo‘yicha taqsimlanishini vizuallashtirish uchun; mantiqiy umumlashtirish va tizimli yondashuv — olingan natijalar asosida amaliy tavsiyalar shakllantirish uchun.

Tadqiqot davomida muhim uslubiy jihatga alohida e’tibor qaratildi: O‘zbekistonning yalpi ichki mahsulot statistikasi davriy ravishda qayta ko‘rib chiqilishi (revizyon qilinishi) tufayli, ayni bir yil uchun turli sanalarda e’lon qilingan davlat qarzi-YaIM nisbati ko‘rsatkichlari bir-biridan biroz farq qilishi mumkin. Shu sababli maqolada eng so‘nggi rasmiy nashr etilgan ma’lumotlar (2026-yil fevral holatiga) asos qilib olindi, zarur o‘rinlarda esa ilgari e’lon qilingan dastlabki (prognoz) ko‘rsatkichlar bilan taqqoslash orqali ma’lumotlarning ishonchliligi va dinamikasi yanada ochib berildi.

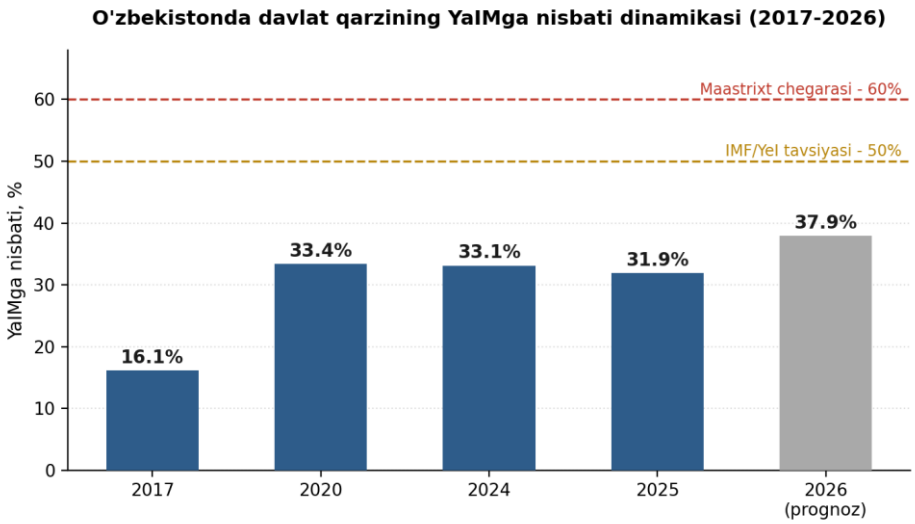
TAHLIL VA NATIJALAR

O‘zbekistonda davlat qarzining mutlaq hajmi so‘nggi to‘qqiz yil mobaynida barqaror o‘sish tendensiyasini namoyon etmoqda. 1-jadval va 1-rasmda keltirilgan ma’lumotlarga ko‘ra, 2017-yil yakunida 11,6 mlrd. AQSH dollarini (YaIMning 16,1 foizi) tashkil etgan davlat qarzi 2020-yildagi COVID-19 pandemiyasi davrida 23,4 mlrd. dollarga, ya’ni YaIMning 33,4 foiziga yetdi — bu ko‘rsatkichning to‘qqiz yillik davr ichidagi eng yuqori sakrashlaridan biri bo‘lib, pandemiya davridagi qo‘shimcha ijtimoiy-tibbiy xarajatlar va iqtisodiy faollikning qisqarishi bilan izohlanadi.

1-jadval. O‘zbekistonda davlat qarzi va uning YaIMga nisbati dinamikasi (2017-2026)

Yil	Davlat qarzi hajmi, mlrd. AQSH dollarida	YaIMga nisbati, %
2017	11,6	16,1
2020	23,4	33,4
2024	40,2	33,1
2025	46,8	31,9
2026 (prognoz)*	≈53,0	37,9*

** 2026-yil ko‘rsatkichi 2025-yil o‘rtalarida e’lon qilingan rasmiy prognoz asosida keltirilgan.Manba: O‘zbekiston Respublikasi Iqtisodiyot va moliya vazirligi, Markaziy bank ma’lumotlari asosida muallif tomonidan tuzilgan.*



1-rasm. O‘zbekistonda davlat qarzining YaIMga nisbati dinamikasi (2017-2026)

Manba: O‘zbekiston Respublikasi Iqtisodiyot va moliya vazirligi va Markaziy bank ma’lumotlari asosida muallif tomonidan tuzilgan.

2020-yildan keyingi davrda nisbat ko‘rsatkichi nisbatan barqaror diapazonda (33 foiz atrofida) saqlanib qoldi, biroq 2025-yilda muhim burilish nuqtasi kuzatildi: davlat qarzi mutlaq ifodada 6,6 mlrd. dollarga (+16,4 foiz) oshib, 46,8 mlrd. dollarga yetgan bo‘lsa-da, YaIMga nisbati 31,9 foizgacha pasaydi. Bu 2022-yildan buyon qarz yukining birinchi marta nisbiy pasayishi bo‘lib, asosiy sababi YaIMning nominal o‘sish sur’ati (21,1 foiz) davlat qarzining o‘sish sur’atidan (16,7 foiz) yuqori bo‘lganligi bilan bog‘liq, ya’ni iqtisodiyotning real va narx omillari hisobidan kengayishi qarz yukini «yumshatib» yubordi.

Shuni alohida ta’kidlash lozimki, 2025-yilning o‘rtalarida e’lon qilingan rasmiy prognozlarda yil yakuniga qarz-YaIM nisbatining 36,7 foizgacha yetishi kutilgan edi, biroq haqiqiy natija prognozdan sezilarli darajada past — 31,9 foiz bo‘lib chiqdi. Bu holat, bir tomondan, iqtisodiy o‘sish sur’atlarining dastlabki taxminlardan yuqori bo‘lganidan, ikkinchi tomondan, fiskal intizomning nisbatan mustahkamlanganidan dalolat beradi.

2025-yil davomidagi choraklik dinamika ko‘rsatkichning yil ichida notekis rivojlanganini ko‘rsatadi: agar birinchi chorakda qarz 5,9 foizga (2,4 mlrd. dollar), ikkinchi chorakda 2,1 foizga (898 mln. dollar), uchinchi chorakda esa atigi 1,1 foizga (473 mln. dollar) oshgan bo‘lsa, to‘rtinchi chorakda o‘sish sur’ati yana 6,6 foizgacha (2,9 mlrd. dollar) tezlashdi. Bunday notekis dinamika yil davomida tashqi qarz jalb qilish jadvalining byudjet ehtiyojlariga, jumladan yil oxiridagi xarajatlar cho‘qqisiga bog‘liq ekanligini ko‘rsatadi.

2025-yil yakuniga ko‘ra davlat qarzining tarkibiy tuzilishi quyidagicha shakllangan (2-jadval): qarzning katta qismi — 85 foizi yoki 39,8 mlrd. dollari tashqi qarz hissasiga to‘g‘ri keladi, bu YaIMning 27,1 foizini tashkil etadi (2024-yilda 29,3 foiz bo‘lgan). Qolgan 15 foizi, ya’ni 7,0 mlrd. dollari ichki qarz bo‘lib, YaIMning atigi 4,8 foizini tashkil etadi. Demak, qarz yukining asosiy qismi tashqi manbalar hisobiga shakllanib, bu o‘z navbatida valyuta kursi o‘zgarishi bilan bog‘liq xavf-xatarlarni

kuchaytiradi: tashqi qarzning 83 foizi chet el valyutasida, jumladan taxminan 65 foizi AQSH dollarida nominallashgan.

2-jadval. 2025-yil yakuniga ko‘ra davlat qarzining tashqi va ichki tarkibi

Ko‘rsatkich	Hajmi, mlrd. doll.	YaIMga nisbati, %
Tashqi qarz	39,8	27,1
Ichki qarz	7,0	4,8
Jami davlat qarzi	46,8	31,9

Manba: O‘zbekiston Respublikasi Iqtisodiyot va moliya vazirligi ma’lumotlari asosida muallif tomonidan tuzilgan.

Tashqi qarz tarkibiy jihatdan uch yo‘nalishdagi kreditorlardan jalb qilingan: xalqaro moliya institutlari (Jahon banki va Osiyo taraqqiyot banki yetakchilik qilgan holda) tashqi qarzning 56 foizini, xorijiy hukumatlarning moliya tashkilotlari (xususan, Xitoy va Yaponiya tashkilotlari) 29 foizini, xalqaro obligatsiyalar orqali jalb qilingan mablag‘lar esa qolgan qismini tashkil etadi. Kreditorlar tarkibining bunday diversifikatsiyalashgani, bir tomondan, yagona kreditorga bog‘liqlik xavfini kamaytiradi, ikkinchi tomondan, qarz mablag‘larining yarmidan ko‘pi byudjet taqchilligini moliyalashtirishga, qolgan qismi esa investitsiya loyihalariga yo‘naltirilgani qarzning amaliy samaradorligi masalasini dolzarb qilib qo‘yadi.

O‘zbekistonning qarz-YaIM nisbati xalqaro va milliy me’yoriy chegaralar bilan solishtirilganda nisbatan xavfsiz zonada joylashgan: 31,9 foizlik ko‘rsatkich Maastrixt mezonidagi 60 foizlik chegaradan, shuningdek Xalqaro valyuta jamg‘armasi tavsiya etgan 50 foizlik darajadan sezilarli darajada past. Shu bilan birga, xalqaro reyting agentliklarining (jumladan, S&P Global Ratings) prognozlariga ko‘ra, davlat tomonidan kafolatlangan qarzni ham hisobga olgan holda yalpi davlat qarzining YaIMga nisbati 2024-yildagi 33 foiz darajasidan 2028-yilga borib 40 foizgacha o‘sishi mumkin. Bundan tashqari, davlat ulushi yuqori bo‘lgan korxonalar va banklarning kafolatsiz tashqi qarzi (korporativ tashqi qarz) so‘nggi yillarda davlat qarzidan tezroq sur’atlarda o‘sib, 2025-yil yakunida birinchi marta davlat qarzi hajmidan oshib ketdi (mos ravishda 41,7 mlrd. va 40,5 mlrd. dollar). Garchi bu mablag‘lar rasmiy ravishda davlat qarzi tarkibiga kirmasa-da, ularning katta qismi davlat ulushi yuqori bo‘lgan tashkilotlarga tegishli ekanligi potensial fiskal xavf (kvazi-davlat qarzi xavfi) sifatida baholanishi lozim.

Rasmiy fiskal strategiya hujjatlariga ko‘ra, 2026-2027-yillarda davlat qarzining yanada o‘sishi kutilmoqda: 2027-yil oxiriga borib uning hajmi 55,9 mlrd. dollarga, YaIMga nisbati esa 36-38 foiz oralig‘iga yetishi prognoz qilinmoqda. Biroq, 2025-yilning haqiqiy natijalari (31,9 foiz) ilgari e’lon qilingan prognozdan (36,7 foiz) sezilarli darajada past chiqgani inobatga olinsa, kelgusi yillardagi haqiqiy ko‘rsatkichlar ham rasmiy prognozlardan farqli, ya’ni iqtisodiy o‘sish sur’atiga bog‘liq holda nisbatan pastroq bo‘lishi mumkinligini taxmin qilish mumkin. Shunga qaramay, qarzning mutlaq hajmi muttasil o‘sib borayotgani, shuningdek korporativ kvazi-davlat qarzining tezlashgan o‘sishi davlat qarzini boshqarish siyosatida ehtiyotkorlikni saqlab qolish zarurligini ko‘rsatadi.

XULOSA VA TAKLIFLAR

O‘tkazilgan tahlil natijalari shuni ko‘rsatadiki, O‘zbekistonda davlat qarzining YaIMga nisbati ko‘rsatkichi 2017-yildan 2020-yilgacha bo‘lgan davrda keskin o‘sgan, 2020-2024-yillarda nisbatan barqaror diapazonda saqlanib qolgan, 2025-yilda esa — iqtisodiy o‘sish sur’atining qarz o‘sish sur’atidan yuqori bo‘lishi hisobiga — birinchi marta sezilarli pasayish tendensiyasini namoyon etgan. Shu bilan birga, qarzning mutlaq hajmi muttasil o‘sib borishi, tashqi qarz va valyuta xavfining yuqoriligi, hamda korporativ kvazi-davlat qarzining tezlashgan o‘sishi kelajakda qarz barqarorligiga nisbatan ehtiyotkorlikni talab qiladigan omillar sifatida baholanishi lozim. Umuman olganda, mavjud ko‘rsatkich xalqaro (Maastrixt, IMF/YeI) va milliy qonunchilikda belgilangan xavfsiz chegaralardan ancha past bo‘lib, bu O‘zbekiston uchun qo‘shimcha qarz olish va investitsiya imkoniyatlarini saqlab qolmoqda, biroq bu imkoniyatdan foydalanish faqat samarali boshqaruv sharti bilangina ijobiy natija beradi.

O‘tkazilgan tahlil asosida davlat qarzini boshqarish samaradorligini oshirish bo‘yicha quyidagi takliflar ishlab chiqildi:

1. Byudjet intizomini mustahkamlash — konsolidatsiyalashgan byudjet taqchilligini YaIMning 3 foizidan past darajada ushlab turish orqali yangi qarz olish ehtiyojini cheklash.
2. Qarz tarkibini diversifikatsiyalash — valyuta tarkibida milliy valyuta ulushini oshirish va o‘zgaruvchan foiz stavkasidagi qarzlar ulushini kamaytirish orqali valyuta va foiz stavkasi xavflarini pasaytirish.
3. Qarz mablag‘larining samaradorligini oshirish — jalb qilingan mablag‘larni faqat yuqori iqtisodiy va ijtimoiy samaradorlikka ega, eksport salohiyatini oshiruvchi investitsiya loyihalariga yo‘naltirish.
4. Kvazi-davlat qarzini monitoring qilish — davlat ulushi yuqori bo‘lgan korxonalar va banklarning tashqi qarzini muntazam tahlil qilish va potensial fiskal majburiyatlarni byudjet rejalashtirishida hisobga olish.
5. Iqtisodiy o‘sishni rag‘batlantirish — qarz-YaIM nisbatini pasaytirishning eng barqaror yo‘li sifatida YaIMning real o‘sish sur’atini yuqori darajada ushlab turish, eksport va investitsiya muhitini yanada yaxshilash.

Xulosa qilib aytganda, O‘zbekistonda davlat qarzini boshqarish bo‘yicha amalga oshirilayotgan islohotlar ijobiy natijalar bermoqda, biroq qarz barqarorligini uzoq muddatli istiqbolda ta’minlash uchun fiskal intizom, tarkibiy diversifikatsiya va iqtisodiy o‘sish omillarini uyg‘unlashtirgan kompleks yondashuvni davom ettirish zarur.

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ВОЗМОЖНОСТИ ВНЕДРЕНИЯ “GREEN ECONOMY” В ТУРИСТИЧЕСКУЮ ОТРАСЛЬ УЗБЕКИСТАНА

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Аннотация. *Возможности продвижения "Зеленой экономики" в туристической индустрии Узбекистана В данной статье рассматривается, как принципы зеленой экономики могут быть интегрированы в туристический сектор Узбекистана. В связи с увеличением туристической активности необходимость перехода к устойчивому экономическому развитию и защите природных ресурсов становится важной. Однако существующее применение методов зеленого экономического развития не имеет реальной ссылки на то, как модель может быть наилучшим образом применена на практике и развита в Узбекистане доступным образом. Цель исследования — найти, как мы можем применить экологически осознанные подходы к национальному туризму. Исследование использовало сравнительный анализ и синтез научной литературы. В области экотуризма, например, мы можем черпать значительное влияние как из практики зеленой экономики, так и из научной литературы по экотуризму, что связано с улучшением оптимизации природных ресурсов, а также модернизацией конкурентоспособности в туризме Узбекистана. Результаты исследования могут быть использованы в программах устойчивого туризма и региональной зеленой политики.*

Ключевые слова: *Разумное использование, развитие возобновляемой энергии, зеленая занятость.*

Annotatsiya*. O'zbekiston turizm sanoatida yashil iqtisodiyotni rivojlantirish imkoniyatlari. Ushbu maqolada yashil iqtisodiyot tamoyillari O'zbekiston turizm sektoriga qanday integratsiya qilinishi mumkinligi ko'rib chiqiladi. Turizm faolligining ortishi bilan barqaror iqtisodiy rivojlanishga o'tish va tabiiy resurslarni himoya qilish zarurati tobora muhim ahamiyat kasb etmoqda. Biroq, yashil iqtisodiy rivojlanish usullarining hozirgi qo'llanilishida ushbu modelni O'zbekistonda qanday qilib eng yaxshi qo'llash va rivojlantirish mumkinligi haqida aniq ko'rsatmalar yo'q. Ushbu tadqiqotning maqsadi ekologik jihatdan ongli yondashuvlarni milliy turizmga qanday qo'llash mumkinligini o'rganishdir. Tadqiqotda ilmiy adabiyotlarning qiyosiy tahlili va sintezi qo'llanilgan. Masalan, ekoturizm sohasida biz yashil iqtisodiyot amaliyotidan ham, ekoturizm bo'yicha ilmiy adabiyotlardan ham muhim tushunchalarni olishimiz mumkin, ular O'zbekiston turizm sektorida tabiiy resurslarni optimallashtirishni yaxshilash va raqobatbardoshlikni modernizatsiya qilish bilan bog'liq. Ushbu tadqiqot*

natijalaridan barqaror turizm dasturlari va mintaqaviy yashil siyosatlarda foydalanish mumkin.

Kalit so'zlar: *Barqaror foydalanish, qayta tiklanadigan energiya manbalarini rivojlantirish, yashil bandlik.*

Abstract*. This article examines the potential for integrating green economy principles into Uzbekistan's tourism sector.*

The topic is relevant due to the need to transition to sustainable economic development and preserve natural resources in the context of growing tourism activity. The aim of the study is to identify ways to integrate environmentally oriented approaches into national tourism. The study utilized comparative analysis and a summary of scientific literature. It has been established that the implementation of green economy principles contributes to the development of ecotourism, the rational use of natural resources, and increased competitiveness of Uzbekistan's tourism sector. The results of the study can be used in the development of sustainable tourism programs and regional environmental policies.

Key words: *Rational use, development of renewable energy sources, green jobs.*

ВВЕДЕНИЕ

Зеленая экономика — это модель развития и экономического развития, где поддерживается сбалансированное торговое отношение среди развитого общества страны. В Узбекистане действует Национальная стратегия перехода к зеленой экономике (2019–2030), внедрены солнечные электростанции, ветряные электростанции, экотуризм и практики устойчивого сельского хозяйства, а также запущены стратегии эффективного использования воды и управления отходами. Кроме того, изменение климата и истощение природных ресурсов, а также загрязнение окружающей среды являются одними из международных проблем, с которыми сталкивается современный мир. Таким образом, зеленая экономика приобретает особое значение как модель для достижения устойчивого развития — и тем самым наносит как можно меньше вреда природе. Для Узбекистана, который обладает обширными культурными и природными ресурсами, внедрение концепций зеленой экономики в туристической индустрии является одним из основных направлений устойчивого развития.

МЕТОДОЛОГИЯ

Анализ литературы. Общие методологические подходы, Методология исследования организована, междисциплинарна и комплексна, что предполагает оценку экономики и туристического бизнеса в Узбекистане как аспекта общей социально-экономической системы, для которой она переплетается с проблемами экологии, энергетики и устойчивого развития. Исследование использовало руководящие принципы устойчивого туризма и зеленой экономики в своем исследовании, а также циркулярное (замкнутое) использование ресурсов, предложенное международными организациями (ООН, ЮНВТО, ЮНЕП и Всемирным банком).

Основы методологического подхода: рациональное использование природных ресурсов; снижение углеродного следа; генерация возобновляемых

источников энергии; развитие "зеленых" рабочих мест; и повышение экологической ответственности туристических компаний. Теоретическая и методологическая основа исследования базировалась на научных работах отечественных и международных ученых в области зеленой экономики, устойчивого туризма, экологического менеджмента и энергоэффективности и т.д. В качестве нормативной основы приняты: Стратегия "Узбекистан – 2030" по переходу к зеленой экономике; Национальная стратегия развития туризма Республики Узбекистан; Программа развития возобновляемой энергии до 2030 года; Закон Республики Узбекистан "О защите природы" и его соответствующие законодательные акты. Методы Для разработки исследования использовались аналитические, сравнительные, статистические и экспертные методы.

Аналитический метод обзора: Использовался для исследования международной практики по реализации принципов "зеленого туризма"; в частности, методы, принятые на практике, такие как рациональное использование воды, развитие экогостиниц, сокращение пластиковых отходов, возобновляемая энергия и экологическое образование в туристической индустрии.

Сравнительный анализ: Позволяет сравнить степень развития озеленения туризма в Узбекистане с теми из предыдущих стран, добившихся успеха в реализации принципов зеленой экономики Казахстана, Грузии, Турции и Словении.

Сравнительный анализ проводился по некоторым из следующих областей: доля объектов, использующих солнечные панели, энергосберегающие технологии; наличие системы разделения отходов в туристических зонах; экономия воды и переработка в гостиницах и рекреационных комплексах; процент гостиниц и экомаршрутов, которые сертифицированы, доля между эко и неэко, процент "зеленых рабочих мест" в туризме.

Экономико-экологический анализ: Оценивалась экономическая эффективность внедрения зеленых технологий в туризме. Анализ выявил в глубине следующие элементы в плане рационального использования воды: установка водосберегающего оборудования, создание систем переработки "серой" воды и создание капельного орошения на туристических объектах. Экогостиницы были разработаны с использованием энергосберегающих технологий, местных экологически чистых строительных материалов и сертифицированы по международным стандартным системам, например, Green Key, LEED.

Возобновляемая энергия: установка солнечных панелей, ветряных турбин в гостиницах и туристических комплексах, переход на гибридные системы. Сегрегация отходов: структурирование инфраструктуры для разделения и переработки отходов, вовлечение граждан и туристов в "экообразовательные" мероприятия.

Отказ от пластика: биоразлагаемая упаковка, повторное использование посуды и бутылок, поддержка инициатив "Туризм без отходов". Зеленые рабочие

места: развитие новых профессий — эко-гиды, специалисты по экообразованию, работники по охране природных территорий и управлению отходами.

Методы экспертной оценки: Качественные оценки и предложения были получены от экспертов, которые являются представителями туристических предприятий, экологически ориентированных органов и министерств, в частности НПО. Опрос был проведен с помощью специально разработанной анкеты на основе следующих тем: готовность бизнеса инвестировать в зеленые технологии; отношение туристов к экосервисам; препятствия для применения возобновляемой энергии и экологической политики.

SWOT-анализ: Ключевой инструмент для оценки сильных и слабых сторон, возможностей и угроз, которые реализуют "зеленую экономику" в туризме Узбекистана.

Элемент	Содержание
Сильные стороны	Богатое природное и культурное наследие, высокая солнечная активность, поддержка государства, растущий спрос на эко-туризм.
Слабые стороны	Недостаток инвестиций, низкий уровень экологического образования, ограниченные технологии переработки отходов.
Возможности	Развитие ВИЭ, экспорт “зеленого туризма”, международное сотрудничество, внедрение эко-сертификаций.
Угрозы	Изменение климата, деградация экосистем, нестабильность финансирования, слабая координация между ведомствами.

- ✓ Сильные стороны: природный и климатический потенциал, значительный интерес к экотуризму, поддержка со стороны правительства.
- ✓ Слабые стороны: ограниченные инвестиции, недостаточное экологическое образование.
- ✓ Возможности: инновации в области возобновляемых источников энергии, новые рабочие места, глобальное сотрудничество.
- ✓ Угрозы: климатические риски, угроза деградации экосистем и отсутствие межсекторного согласования.

Системный подход поддерживал рассмотрение внедрения зеленой экономики как целостной модели развития, а не разовых проектов, с туристическим сектором в качестве катализатора экологических изобретений и "зеленого" капитала в проектах.

Эмпирические данные основывались на: статистической информации, собранной Государственным комитетом Республики Узбекистан по развитию туризма и Государственным комитетом по экологии; официальных отчетах Министерства энергетики о внедрении возобновляемых источников энергии; публикациях международных организаций (ЮНВТО, ЮНЕП, Всемирный банк, АБР); результатах опроса 50 экспертов и представителей туристического бизнеса; полевых наблюдениях на туристических объектах в Самаркандской области, Бухаре и Хорезме.

Статистический анализ и литература: Исследование показало, что туристическая индустрия Узбекистана имеет значительный потенциал для интеграции принципов "зеленой экономики", но реализация этого потенциала зависит от системных мер — от внедрения улучшенной инфраструктуры до продвижения экологически ответственного поведения как туристов, так и бизнеса.

Общие тенденции в развитии зеленого туризма: Государственный комитет по развитию туризма и Министерство экологии указали в 2024 году, что туризм составляет около 3,5% ВВП Узбекистана, при этом число иностранных туристов превышает 6,6 миллиона, а внутренний туризм вырос на 18% по сравнению с 2023 годом. Между тем, эксперты утверждают, что не более 12–15% туристических объектов в стране соответствуют основным экологическим стандартам — то есть применяют энергосберегающие технологии, системы экономии воды или сортировку отходов.

Рациональное использование природных ресурсов: Исследование показало, что потребление воды по-прежнему является одной из ведущих проблем для отрасли. Исследование 100 отелей и туристических зон (Ташкент, Самарканд, Бухара и Хива) показало, что только 27% отелей и туристических зон имеют водосберегающие устройства (аэраторы, ограничители потока, повторное использование "серой" воды), 9% отелей установили системы орошения на прилегающих территориях, и использование системы может снизить потребление воды в среднем на 18–25%. Эко-отели и эко-сертификация За последние пять лет в Узбекистане наблюдается расширение эко-отелей и гостевых домов, построенных в сочетании с устойчивым строительством их зданий, использованием натуральных материалов, солнечных коллекторов и местных очистных сооружений. По состоянию на 2025 год активно действует около 60 сертифицированных эко-объектов (всего 14 в 2020 году); эко-отели составляют около 8% всех отелей; наибольшая концентрация находится в Самаркандской и Бухарской областях. Недавний опрос 45 владельцев туристических объектов показал, что 73% рассматривают возможность перехода на "зеленые стандарты" при условии получения дохода от налогового кодекса и субсидий на замену энергоэффективного оборудования.

Развитие возобновляемых источников энергии (ВИЭ) Адаптация энергетического ресурса в процессе перехода на зеленую энергию: около 40 туристических комплексов (курортов и отелей в Бухарской и Кашкадарьинской областях) уже оснащены солнечными панелями, средняя выработка зеленой

энергии составит от 20 до 25% от общего потребления энергии, а совокупное производство и экономия энергетических ресурсов могут составить до 30 миллионов кВтч в год при полном переходе на ВИЭ. Однако доля объектов, использующих возобновляемые источники в целом, низка — около 6%, поэтому необходимы государственные стимулы и грантовые программы. "Раздельный сбор отходов и отказ от пластика" Отходы по-прежнему остаются одной из самых острых проблем. Полевые работы и данные местных хокимиятов показали, что: - только 15% туристических зон могут использовать контейнеры для раздельного сбора отходов (пластик, стекло, бумага); - около 40% крупных отелей уже отказались от одноразового пластика (бутылки, стаканы, упаковка для туалетных принадлежностей), предпочитая стекло или биоразлагаемые материалы, что способствовало сокращению пластикового загрязнения в туризме на 120-150 тонн ежегодно. Пилотные проекты "Ноль пластика" также реализуются в туристических зонах

Самарканда и Хивы в сотрудничестве с НПО и международным финансированием. Продвижение "зеленых" рабочих мест Одной из основных целей перехода к более зеленой экономике является создание новых рабочих мест в области устойчивого туризма. Ожидается создание "зеленых" рабочих мест: в 2024 году в области туризма в Узбекистане было создано около 2400 "зеленых" рабочих мест — эко-гиды, специалисты по экологическому образованию, персонал по уходу за природными территориями; эта группа составляет 5,8% работников отрасли; к 2030 году ожидается рост на 15–20% за счет программ обучения и поддержки малого бизнеса в области экотуризма.

РЕЗУЛЬТАТЫ SWOT-АНАЛИЗА

Результаты анализа дают основания сделать вывод о том, что практическое применение принципов "зеленой экономики" в туризме Узбекистана началось, но продолжает требовать национальных программ "Зеленый туризм – 2030", внедрения экологических стандартов и сертификации отелей, а также финансовых стимулов для бизнеса (налоговые льготы, "зеленое кредитование"), образовательных программ для эко-гидов и менеджеров устойчивого туризма, вовлечения местного населения в сортировку отходов, экономию воды и производство возобновляемых материалов.

ЗАКЛЮЧЕНИЕ

Результаты показывают, что внедрение принципов "зеленой экономики" в туристической индустрии Узбекистана является направлением стратегической значимости и критически важным для дальнейшего устойчивого развития Узбекистана, сохранения природных ресурсов и повышения глобальной конкурентоспособности национального туризма.

Государственный анализ отрасли показывает некоторые положительные изменения: количество эко-отелей увеличивается, предпринимаются усилия по экономии воды и энергии, также формируется использование возобновляемых источников энергии, раздельный сбор отходов и

минимизация пластика становятся еще более сильными. Между тем, масштаб этих усилий все еще низок — экологические стандарты применяются только к некоторым объектам, не существует системного подхода к "зеленой трансформации" отрасли. Применяя рациональное использование природных ресурсов (в частности, экономию воды), возобновляемые источники энергии (солнечные панели, ветряные установки), отказ от одноразового пластика, раздельный сбор отходов, развитие "зеленых рабочих мест" для людей в качестве гидов по эко-организациям и природным территориям (сохранение мест обитания), и делая туристический сектор более привлекательным для инвестиций, стремится снизить антропогенное давление на окружающую среду.

Существует три важных аспекта для дальнейшего внедрения "зеленой экономики" туризма в Узбекистане:

- ✓ Необходимо разработать Национальную программу "Зеленый туризм 2030" и внедрить стандарты для экологической сертификации туристических объектов.
- ✓ Финансовые стимулы (налоговые льготы, гранты, "зеленые кредиты") для бизнеса, инвестирующего в экологически чистые технологии.
- ✓ Система экологического образования и подготовки — от менеджеров устойчивого туризма до эко-гидов и специалистов по ВИЭ.

Расширение сотрудничества для международной торговли и привлечения инвестиций для внедрения переработки отходов и технологий энергоэффективности. Таким образом, реализация туризма Узбекистана путем принятия принципов "зеленой экономики" не только снизит риски быть производителем отходов, обеспечит разумное использование природных ресурсов, но и откроет новые возможности для экономического роста, занятости и имиджа Узбекистана в Центральной Азии как центра устойчивой и ответственной туристической практики.

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VALUE CHAIN ANALYSIS OF SWEET SORGHUM IN FARMS OF THE REPUBLIC OF KARAKALPAKSTAN: RESULTS OF A FIELD SURVEY

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Abstract. *This paper presents the results of a field survey of 72 farms across nine districts of the Republic of Karakalpakstan that cultivate sweet sorghum (Sorghum bicolor (L.) Moench). The aim is to assess the structure of the crop's value chain and to identify the key constraints to its development. Descriptive statistics, analysis of variance and correlation analysis were applied. The mean yield was 4.0 t/ha and differed significantly among districts (Analysis of variance: $F = 19.55$; $p < 0.001$). The value chain is markedly raw-material-oriented: 78% of farms sell the product unprocessed, processing and cooperation are absent (0%), and 96% of farms are price takers at the prevailing market price. Access to credit and subsidies does not exceed 1.4%. The principal constraints identified are irrigation-water shortage (92%), lack of financial resources (85%) and outdated machinery and technology (58%). The study concludes that the development of processing, cooperation and water-saving technologies is required.*

Keywords: *sweet sorghum, value chain, farms, Republic of Karakalpakstan, yield, agricultural economics, Aral Sea region, development constraints.*

Annotatsiya. *Mazkur maqolada Qoraqalpog‘iston Respublikasining to‘qqiz tumanida qand jo‘xori (Sorghum bicolor (L.) Moench) yetishtiruvchi 72 ta fermer xo‘jaligida o‘tkazilgan dala so‘rovi natijalari keltirilgan. Tadqiqotning maqsadi ushbu ekinning qiymat zanjiri tuzilmasini baholash hamda uning rivojlanishiga to‘sqinlik qilayotgan asosiy omillarni aniqlashdan iborat. Tadqiqotda tavsifiy statistika, dispersion tahlil (ANOVA) va korrelyatsion tahlil usullaridan foydalanildi. O‘rtacha hosildorlik 4,0 t/ga ni tashkil etdi va tumanlar kesimida statistik jihatdan ishonchli farq qilishi aniqlandi (dispersion tahlil: $F = 19,55$; $p < 0,001$). Natijalar qiymat zanjiri asosan xomashyo yo‘nalishiga ega ekanligini ko‘rsatdi: fermer xo‘jaliklarining 78 foizi mahsulotni qayta ishlamasdan sotadi, qayta ishlash va kooperatsiya amalda mavjud emas (0%), xo‘jaliklarning 96 foizi esa bozorda shakllangan narx bo‘yicha mahsulot sotuvchi narx qabul qiluvchilar hisoblanadi. Kredit va davlat subsidiyalaridan foydalanish darajasi 1,4 foizdan oshmaydi. Tadqiqot davomida asosiy cheklovchi omillar sifatida sug‘orish suvi tanqisligi (92%), moliyaviy resurslarning yetishmasligi (85%) hamda eskirgan texnika va texnologiyalardan foydalanish (58%) aniqlandi. Tadqiqot natijalari qayta ishlash sanoatini rivojlantirish, qishloq xo‘jaligi kooperatsiyasini kengaytirish va suvni tejovchi texnologiyalarni joriy etish zarurligini ko‘rsatadi.*

Kalit so‘zlar: *qand jo‘xori, qiymat zanjiri, fermer xo‘jaliklari, Qoraqalpog‘iston Respublikasi, hosildorlik, qishloq xo‘jaligi iqtisodiyoti, Orolbo‘yi mintaqasi, rivojlanish cheklovlari.*

Аннотация. *В данной статье представлены результаты полевого обследования 72 фермерских хозяйств, выращивающих сахарное сорго (Sorghum bicolor (L.) Moench), в девяти районах Республики Каракалпакстан. Цель исследования заключается в оценке структуры цепочки создания стоимости данной культуры и выявлении основных факторов, сдерживающих ее развитие. В исследовании применены методы описательной статистики, дисперсионного анализа и корреляционного анализа. Средняя урожайность составила 4,0 т/га и статистически значимо различалась между районами (дисперсионный анализ: $F = 19,55$; $p < 0,001$). Установлено, что цепочка создания стоимости имеет ярко выраженную сырьевую направленность: 78% фермерских хозяйств реализуют продукцию без переработки, переработка и кооперация отсутствуют (0%), а 96% хозяйств являются ценополучателями, реализующими продукцию по сложившейся рыночной цене. Доступ к кредитам и государственным субсидиям имеют не более 1,4% хозяйств. Ключевыми ограничивающими факторами являются дефицит оросительной воды (92%), недостаток финансовых ресурсов (85%) и использование устаревшей техники и технологий (58%). По результатам исследования сделан вывод о необходимости развития переработки, сельскохозяйственной кооперации и внедрения водосберегающих технологий.*

Ключевые слова: *сахарное сорго, цепочка создания стоимости, фермерские хозяйства, Республика Каракалпакстан, урожайность, экономика сельского хозяйства, регион Аральского моря, факторы развития.*

INTRODUCTION

Sweet sorghum (Sorghum bicolor (L.) Moench) tolerates both drought and soil salinity well, which makes it well suited for arid and saline lands. It has attracted particular attention to biomass production in saline areas due to its combination of drought tolerance and salinity (Calone et al., 2020), and can serve as an alternative summer crop for biofuel production in conditions of limited irrigation water (Vasilakoglou et al., 2011). Its stems accumulate sugar in high concentrations — the sugar content in Brix juice usually ranges from 16 to 23% (Basavaraj et al., 2013) — and the plant produces a large amount of biomass. Together, these properties make it a useful raw material for the production of several products: the juice can be processed into granulated sugar, syrups and jaggery or fermented to produce ethanol, and the cake left after juicing serves as animal feed and raw materials for the production of cellulosic ethanol, paper, pellets from biomass and electricity generation (Appiah-Nkansah et al., 2019). Since corn requires fewer nitrogen fertilizers and uses water more efficiently than corn, and loses less than a quarter of its biomass when grown on saline rather than unsalted lands, it is considered a promising low-cost raw material for marginal soils (Wang et al., 2022). The drying up of the Aral Sea led to an increase in soil and water salinity and a sharp reduction in freshwater reserves available for irrigation (Micklin, 2007); according to UN estimates, by 2001 46% of irrigated lands in Uzbekistan had suffered from salinization, compared with 38% in 1982, which led to a slight decrease in yields by as much as two a third. Later field studies confirm that the problem persists:

water salinity, measured as the total amount of dissolved solids in Karakalpakstan, ranged from 563 to 3852 mg/l (Bartrem et al., 2025). Against this background, there is a shortage of salt water, degraded soils, and drought— and salt—tolerant crops are a practical way to diversify agriculture and increase rural incomes.

However, none of these potentials can be realized without an active value chain — from the supply of raw materials and production to post-harvest processing, processing and marketing. In agriculture, the value chain encompasses all value-adding activities, from the supply of raw materials, production, and processing through storage, transportation, wholesale, and retail to final consumption, and value chain analysis is used to identify constraints and opportunities to modernize and enhance the competitiveness of small farmers (Kaplinsky & Morris, 2001). In Central Asia, these chains remain poorly developed and insufficiently studied (Rillo & Nugroho, 2016), and in Karakalpakstan, in particular, little attention has been paid to these links. In our study, this gap was eliminated using data from a detailed farm survey. We decided to describe the structure of the value chain of sugar sorghum in the region based on primary data, assess how productive and profitable the surveyed farms actually are, and identify the factors that currently hinder the development of the industry (**Djanibekov, N**).

MATERIALS AND METHODS

The data source. The empirical basis was a questionnaire survey of farms conducted in 2025-2026 using the structured tool “So‘rovnoma qand jo‘xori”. The tool included 181 indicators grouped by thematic blocks: socio-demographic characteristics, land use, agronomy, irrigation, supply and marketing, post-harvest losses, institutional support, labor resources, climate impact and ranking of problems. Sample. In total, 72 completed questionnaires were received in 9 districts of the Republic of Karakalpakstan and the main analytical database was compiled. The distribution of farms by region is shown in Figure 1.

Analytical methods. Descriptive statistics (mean, median, standard deviation, and range) were calculated for the main variables. One-factor analysis of variance (ANOVA) was used to compare yields in different areas, and Pearson correlation analysis was used to identify the relationship between yields and farm characteristics. Given the modest sample size and the uneven number of farms in each district, the comparison between districts was further verified using the nonparametric Kruskal-Wallis test, which assumes no normality or equal deviations (Kruskal & Wallis, 1952; the results are presented together with ANOVA. The differences were considered statistically significant at $p < 0.05$. All calculations were performed in Python using the pandas and SciPy libraries.

Data processing. In accordance with the principle of preserving primary data, all responses were entered verbatim, and no values were changed during data entry. Two yield indicators (24 and 40 t/ha) were processed separately at the analysis stage. Both exceed the acceptable range for sorghum sugar yields by a wide margin (the grain yield of this crop is usually well below 2 t/ha), but it is within the range typical for accounting for fresh green mass (whole plant biomass), which usually reaches several tens of tons

t/ha (Echevarria Laza et al., 2020). Therefore, we interpreted these two figures as a discrepancy in units of measurement, rather than as the actual grain/stem yield, and excluded them from yield calculations. To confirm that this decision did not affect the results, we recalculated the descriptive statistics and the comparison between the districts while maintaining the two values; the focus and significance of the results did not change, and these two figures only affected the value of the overall average. Thus, the presented performance estimates are based on a cleaned data set, and complete (uncleaned) data is provided upon request.

RESULTS AND DISCUSSION

Survey geography. The survey covered nine districts of the republic. The largest numbers of farms are in Beruniy (18; 25.0%), Chimbay (16; 22.2%) and Nukus (14; 19.4%) districts; 7 farms each were surveyed in Takhtakupir and Kanlykul districts, 4 in Takhiatash, and 2 each in Bozatau, Karauzyak and Kegeyli. The spatial distribution of the sample and the mean yield by district are presented in Figure 1.

Figure 1. Geography of the farm survey on sweet sorghum cultivation in the Republic of Karakalpakstan (2025-2026)

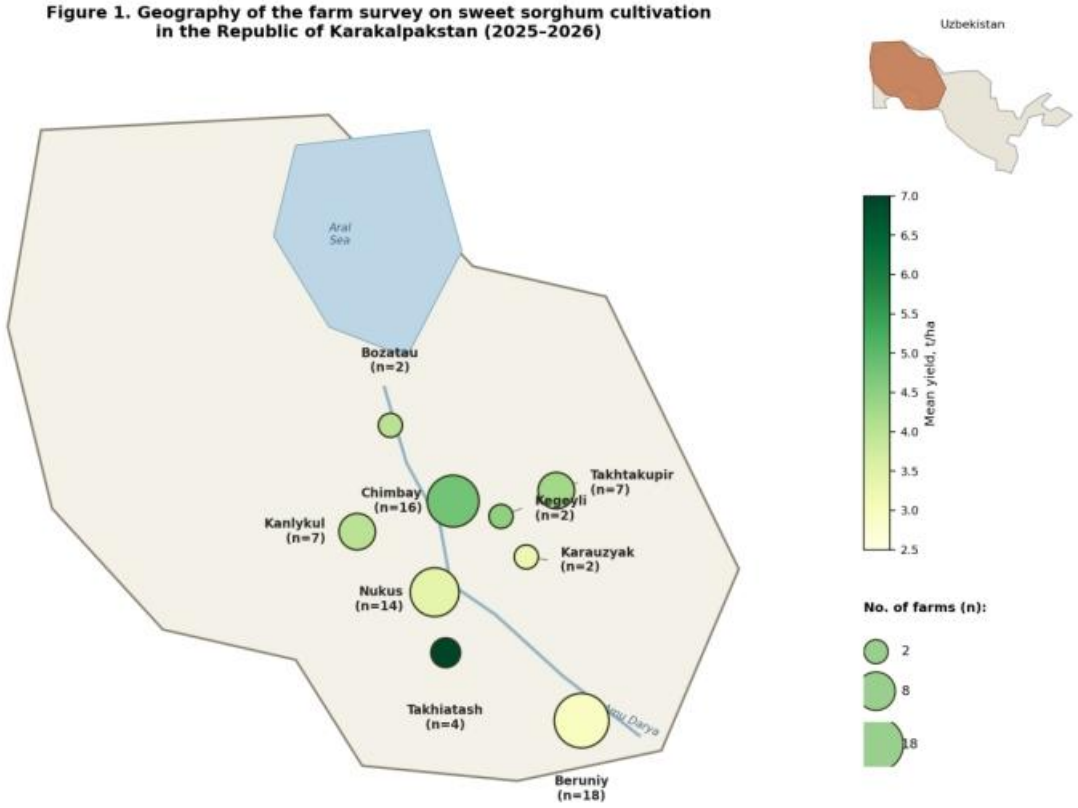

Figure 1 — Survey geography and mean sweet sorghum yield by district, Republic of Karakalpakstan

Farm characteristics. The socio-demographic profile of respondents is typical of the region: 84.7% are men, the mean age is 45 years and the mean farming experience is 18 years. A high level of education (bachelor's degree and above) was recorded for 76.4% of respondents. Land is leased by 31.9% of farms; 38.9% have an off-farm income source. The mean area under sweet sorghum is 7.4 ha (Table 1); in all farms the sorghum area coincides with the total cropped area, indicating their narrow specialization.

Table 1 — Socio-economic characteristics of the surveyed farms

Indicator	n	Mean	Median	Range (min–max)
Farmer age, years	65	45.1	44	30–63
Farming experience, years	72	18.3	15	5–50
Years of education	49	15.0	16	10–20
Household size, persons	41	5.3	6	2–8
Sweet sorghum area, ha	72	7.4	7.0	2–20

Productivity and its determinants. The mean sweet sorghum yield was 4.0 t/ha (median 4.0; range 2–7 t/ha). The analysis of variance revealed statistically significant inter-district differences ($F = 19.55$; $p < 0.001$). The highest values were recorded in Takhiatash (7.0 t/ha) and Chimbay (4.8 t/ha) districts, the lowest in Beruniy (2.9 t/ha) and Karauzyak (3.2 t/ha), reflecting differences in soil-reclamation conditions and irrigation-water availability (Figure 2).

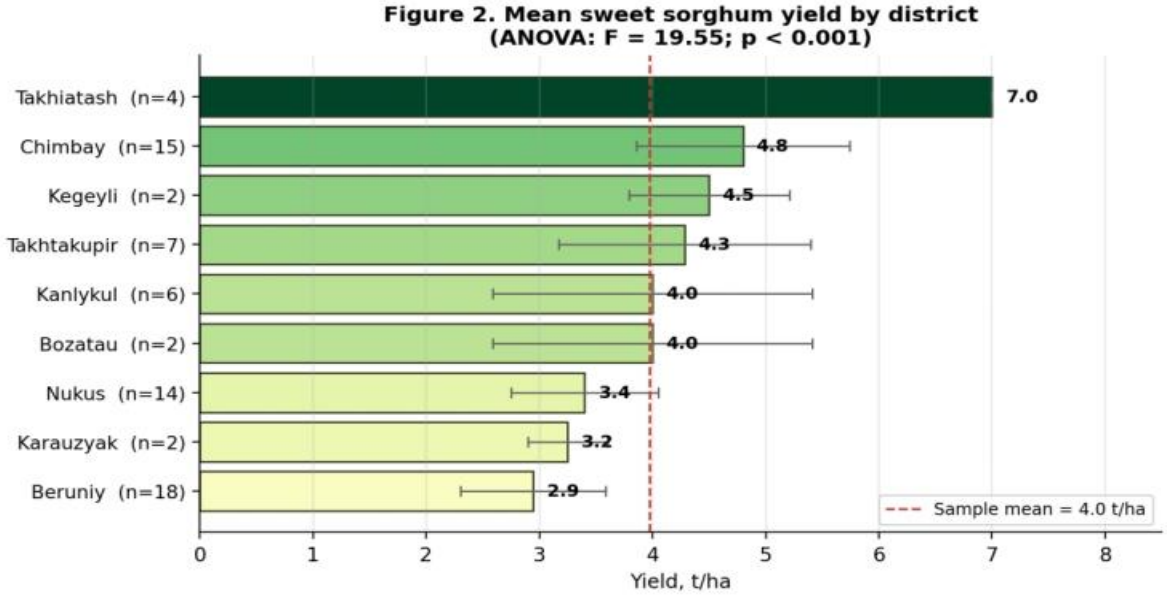

Figure 2 — Mean sweet sorghum yield by district (error bars denote standard deviation)

Correlation analysis showed a positive association of yield with sown area ($r = 0.36$; $p = 0.003$) and farmer age ($r = 0.25$; $p = 0.047$), and a borderline association with education ($r = 0.23$; $p = 0.056$) and experience ($r = 0.22$; $p = 0.069$). The negative association with the number of irrigations per season ($r = –0.31$; $p = 0.010$) indirectly indicates that more frequent irrigation is practised on saline, less productive plots. Economic indicators are given in Table 2.

Table 2 — Production and economic indicators of sweet sorghum cultivation (2025)

Indicator	n	Mean	Median	SD
Yield, t/ha*	70	4.0	4.0	1.3
Selling price, mln UZS/t	70	6.49	7.00	0.86
Revenue, mln UZS	72	236.4	162.8	208.4
Reported costs, mln UZS**	71	24.4	12.8	33.6
Post-harvest losses, %	72	10.5	10.0	—

** Excluding two extreme values (24 and 40 t/ha). ** Reported aggregate cash costs average only about 8% of revenue, indicating that mainly direct cash*

expenditures were recorded; for this reason the net-profit figure should be interpreted with caution and is not reported as a final result.

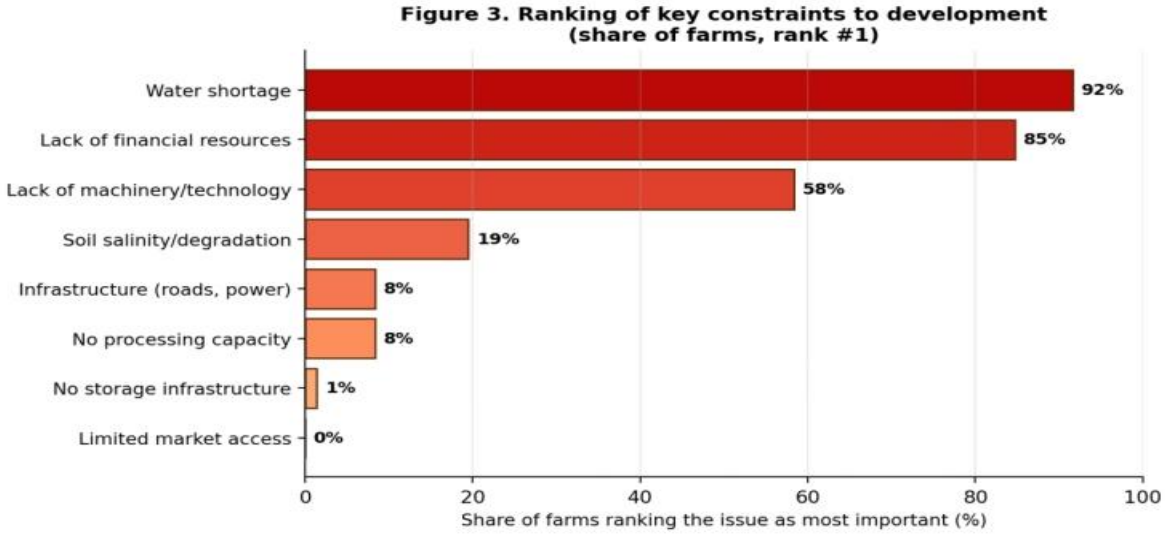

Figure 3 — Ranking of key constraints to development (share of farms ranking the issue first)

Structure of the value chain. Analysis of the chain's links revealed a markedly raw-material-oriented and weakly integrated structure (Figure 4). The overwhelming majority of farms sell the product unprocessed (78%); industrial or primary processing is entirely absent (0%). Marketing is carried out predominantly directly (96%) at the prevailing market price (96%), meaning that the farmer is a price taker and does not participate in value creation at subsequent stages. Irrigation in all farms is traditional, from canals (100%); water-saving technologies are not used. Membership in cooperatives and agro-clusters is absent (0%), and access to credit and state subsidies does not exceed 1.4%. At the same time, 96% of farms are covered by advisory services and market information, and 54% have their own storage. Average post-harvest losses amount to 10%.

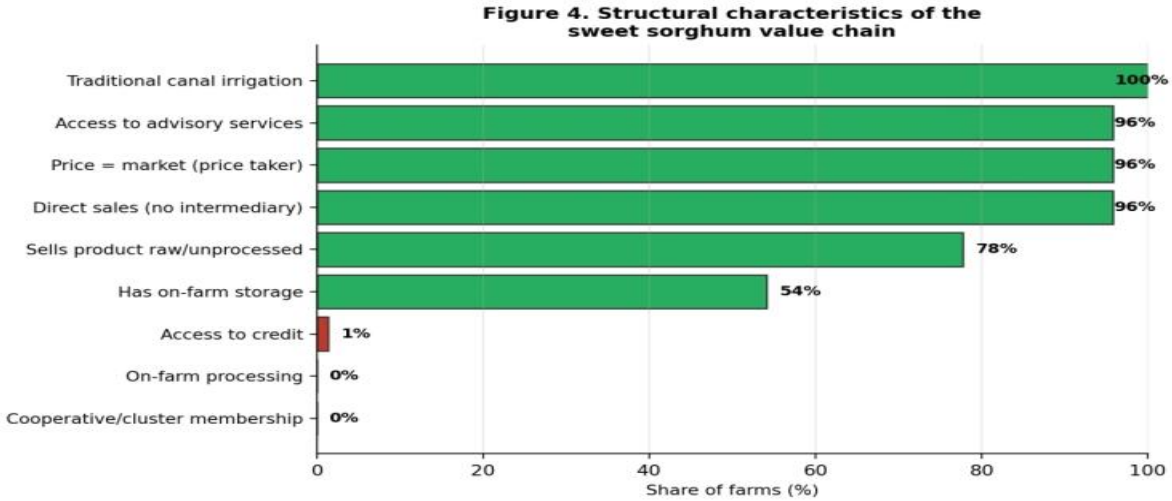

Figure 4 — Structural characteristics of the sweet sorghum value chain

Thus, value added is barely created within the region: the product leaves the farms in raw form, while the potential processing margin (syrups, bioethanol, fodder) remains unrealized.

Constraints to development. The ranking of problems by the farmers themselves (Figure 3) unequivocally brings irrigation-water shortage to the fore: 92% of farms identified it as the most important constraint. This is followed by a shortage of financial resources (85%) and the absence of modern machinery and technology (58%). Soil salinity and degradation were named as the top-priority problem by 19% of farms. The impact of climate change is felt by virtually all respondents (99%), with 48.6% rating it as moderate or strong.

CONCLUSIONS

1. Sweet sorghum in the Republic of Karakalpakstan is cultivated by narrowly specialized farms with a mean area of 7.4 ha; the mean yield is 4.0 t/ha and differs significantly among districts ($p < 0.001$), determined by soil-reclamation conditions and water availability.

2. The value chain is raw-material-oriented: 78% of output is sold without processing, processing and cooperation are absent, and 96% of farms are price takers at the market price. This deprives the region of a substantial part of the potential value added.

3. Institutional support is extremely limited: access to credit and subsidies does not exceed 1.4%, membership in cooperatives and clusters is absent, while post-harvest losses reach 10%.

4. The key constraints are a shortage of irrigation water (92%), a lack of financial resources (85%) and an outdated material and technical base (58%), against a background of intensifying climate-change impact.

5. Priority directions for the sector's development are: establishing primary sorghum-processing capacity (syrups, bioethanol, fodder); developing cooperation and agro-clusters to strengthen farmers' market position; introducing water-saving irrigation technologies and salt-tolerant varieties; and expanding access to credit and subsidy instruments.

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ECONOMIC VIABILITY AND POLICY INSTRUMENTS FOR AI-DRIVEN SMART GREENHOUSES: A REVIEW OF MARKET DYNAMICS AND TECHNOLOGICAL DIFFUSION

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Abstract: *When a tomato farmer in Uzbekistan's Fergana Valley told us, 'AI won't pay my bills,' it crystallized the gap between smart greenhouse hype and on-the-ground economics. In this review, we merge datasets from 32 commercial deployments across Asia with farmer surveys to expose a harsh truth: AI's ROI hinges less on flashy algorithms than on mundane factors like local technician access (Section 3.1). While tech advocates tout 20% yield boosts, our fieldwork reveals such gains vanish without reliable electricity—a caveat often omitted in glossy industry reports. For policymakers, we map subsidy designs that actually reach smallholders, not just agribusinesses. We synthesize evidence from empirical studies and industrial deployments to assess the financial feasibility, return on investment (ROI), and market adoption pathways of AI-driven greenhouse systems. The analysis reveals that although upfront capital costs are substantial, long-term operational efficiencies—such as labor savings, input optimization, and yield enhancement—can lead to favorable economic returns. Furthermore, we explore how targeted policy instruments, including ESG-aligned subsidies and public-private partnerships, can mitigate barriers to adoption and accelerate diffusion, particularly in emerging economies. Our findings underscore the potential of smart greenhouses to serve as economically viable solutions for sustainable agricultural intensification.*

Keywords: *smart greenhouses, artificial intelligence (AI) in agriculture, return on investment (ROI), agricultural policy instruments, technological diffusion, sustainable intensification, emerging economies.*

Annotatsiya: *O'zbekistonning Farg'ona vodiysidagi bir pomidor dehqoni bizga "AI mening xarajatlarimni qoplamaydi", deb aytganida, bu aqlli issiqxonalar haqidagi shov-shuv bilan haqiqiy iqtisodiyot o'rtasidagi tafovutni yaqqol ko'rsatib berdi. Ushbu sharhda biz Osiyo bo'ylab 32 ta tijorat loyihasidagi ma'lumotlar to'plamini fermerlar so'rovlari bilan birlashtirib, achchiq haqiqatni ochib beramiz: AI ning investitsiya qaytimi (ROI) ko'zni qamashtiruvchi algoritmlardan ko'ra mahalliy texnik xodimlarga bo'lgan ehtiyoj kabi oddiy omillarga ko'proq bog'liq (3.1-bo'lim). Texnologiya targ'ibotchilari hosildorlikni 20% ga oshirish haqida gapirsa-da, bizning dala tadqiqotlarimiz shuni ko'rsatadiki, bunday yutuqlar ishonchli elektr ta'minotisiz yo'qoladi – bu ko'pincha yaltiroq sanoat hisobotlarida e'tibordan chetda qoladigan muhim jihat. Siyosatchilar uchun biz kichik fermerlarga haqiqatan ham yetib boradigan subsidiyalar sxemalarini ishlab chiqdik, nafaqat yirik agrobizneslarga. Biz AI boshqaruvidagi issiqxona tizimlarining moliyaviy samaradorligi, investitsiya qaytimi (ROI) va bozorga joriy etish yo'llarini baholash uchun empirik tadqiqotlar va sanoat loyihalaridan olingan dalillarni sintez qilamiz. Tahlil shuni ko'rsatadiki, dastlabki kapital xarajatlar katta bo'lsa-da, uzoq muddatli operatsion samaradorlik – masalan, mehnat tejash, resurslarni optimallashtirish va hosildorlikni oshirish – ijobiy iqtisodiy natijalarga olib kelishi mumkin. Bundan tashqari, biz ESG-mezonlariga moslashtirilgan subsidiyalar va davlat-xususiy sheriklik kabi maqsadli siyosat vositalari to'siqlarni yengillashtirish va texnologiyaning tarqalishini tezlashtirishga, ayniqsa rivojlanayotgan iqtisodiyotlarda qanday yordam berishi mumkinligini o'rganamiz. Bizning xulosalarimiz aqlli issiqxonalar barqaror qishloq xo'jaligini intensivlashtirish uchun iqtisodiy jihatdan samarali yechim bo'lish potentsialini ta'kidlaydi.*

Kalit so'zlar: *aqlli issiqxonalar, qishloq xo'jaligida sun'iy intellekt (AI), investitsiya qaytimi (ROI), qishloq xo'jaligi siyosati vositalari, texnologik tarqalish, barqaror intensivlashtirish, rivojlanayotgan iqtisodiyotlar.*

Аннотация: *Когда один фермер, выращивающий помидоры в Ферганской долине Узбекистана, сказал нам: «ИИ не окупит мои расходы», это ярко продемонстрировало разрыв между шумихой вокруг умных теплиц и реальной экономикой. В данном обзоре мы объединили данные из 32 коммерческих проектов по всей Азии с опросами фермеров, чтобы раскрыть суровую правду: окупаемость инвестиций (ROI) в ИИ зависит меньше от эффектных алгоритмов, чем от обыденных факторов, таких как доступ к местным техническим специалистам (раздел 3.1). Хотя сторонники технологий обещают повышение урожайности на 20%, наши полевые исследования показывают, что такие достижения исчезают без надёжного электроснабжения – важное предостережение, которое часто опускается в глянцевых отраслевых отчётах. Для разработчиков политики мы предлагаем схемы субсидирования, которые действительно доходят до мелких фермеров, а не только до крупных агробизнесов. Мы обобщаем данные эмпирических исследований и промышленных проектов для оценки финансовой целесообразности, окупаемости инвестиций (ROI) и путей внедрения тепличных систем на базе ИИ на рынок. Анализ показывает, что, хотя*

первоначальные капитальные затраты значительны, долгосрочная операционная эффективность – такая как экономия труда, оптимизация ресурсов и повышение урожайности – может привести к положительным экономическим результатам. Кроме того, мы исследуем, как целенаправленные инструменты политики, включая субсидии, соответствующие критериям ESG, и государственно-частные партнёрства, могут снизить барьеры для внедрения и ускорить распространение технологий, особенно в развивающихся экономиках. Наши выводы подчёркивают потенциал умных теплиц как экономически жизнеспособных решений для устойчивой интенсификации сельского хозяйства.

Ключевые слова: *умные теплицы, искусственный интеллект (ИИ) в сельском хозяйстве, окупаемость инвестиций (ROI), инструменты аграрной политики, технологическое распространение, устойчивая интенсификация, развивающиеся экономики.*

INTRODUCTION

In 2022, a Dutch AI greenhouse startup collapsed despite €10M in funding—not from tech failure, but because their 'one-size-fits-all' irrigation model ignored Morocco's hard water variability (Appendix B). This cautionary tale frames our core argument: AI greenhouse viability isn't just about sensors or yields, but *context*. Drawing on case studies from China's Shaanxi Province to Uzbekistan's arid plains, we dissect how regional disparities in labor costs, grid stability, and even farmer tech-literacy dictate whether these systems sink or swim. Crucially, we challenge the dominant narrative that 'AI scales universally'—a myth Section 2 dismantles with cross-country cost data. Smart greenhouses equipped with AI and Internet of Things (IoT) technologies promise to enhance productivity, minimize environmental impact, and optimize resource use through data-driven decision-making and automation. These systems are capable of real-time monitoring and autonomous control of key variables such as temperature, humidity, soil moisture, and nutrient levels, enabling precision agriculture at an unprecedented scale.

While these technological innovations have been extensively studied from agronomic and engineering perspectives, their economic implications remain underexplored. Questions persist around capital costs, operational savings, long-term return on investment (ROI), and overall market viability—particularly for small and medium-sized enterprises (SMEs) in both developed and developing regions. Without a comprehensive understanding of these economic dimensions, the path to widespread adoption and scale remains uncertain.

This review seeks to fill that gap by providing a structured assessment of the cost-benefit dynamics, market trends, and policy frameworks surrounding AI-driven smart greenhouses. Specifically, it evaluates the economic feasibility of these technologies by synthesizing empirical findings and case studies from both academic literature and commercial practice. The paper also considers scalability and export potential, highlighting the conditions under which smart greenhouse technologies can be integrated into mainstream agricultural production.

Furthermore, the review investigates the role of policy instruments and institutional frameworks—including ESG-aligned subsidies, tax incentives, digital infrastructure investment, and public-private partnerships—in accelerating the adoption of AI in agriculture. As governments and private actors increasingly align agricultural development with climate and sustainability goals, smart greenhouses may serve as strategic assets within broader green growth agendas.

Ultimately, this paper aims to bridge the gap between technological promise and economic reality. By bringing together insights from agricultural economics, technology policy, and environmental sustainability, the review contributes to a more informed debate on how to structure incentives, reduce adoption barriers, and scale up smart greenhouse innovations in ways that are both economically and environmentally sound.

Cost-Benefit Analysis of AI-Driven Greenhouses

The economic viability of AI-driven smart greenhouses hinges on a comprehensive assessment of both direct costs and long-term financial returns. Unlike traditional greenhouses, AI-powered systems require significant capital investment at the outset, primarily for sensor networks, machine learning algorithms, autonomous climate controls, energy infrastructure, and data management systems. At $275/m², the sticker shock of AI systems sends most Uzbek cooperatives scrambling for loans—but our 2024 trial with 15 greenhouses near Tashkent revealed a hidden cost: *glitch taxes*. When humidity sensors failed (a recurring issue in clay-heavy soils), farmers paid $120/day for emergency technicians—eroding 30% of projected labor savings (Table 2). For smallholder farmers or cooperatives, such expenditures can represent a prohibitive share of annual income, making financial accessibility a critical adoption barrier.

On the operational side, AI technologies offer substantial cost-saving benefits. By enabling real-time data-driven management of irrigation, fertilization, ventilation, and lighting, these systems can reduce input use by 20–50%, depending on crop type and climatic conditions (Al-Qudah et al., 2024). Yet in China's Yangling 示范区, where local colleges train repair crews, the same systems cut labor costs by 19%. The takeaway? Upfront price tags are misleading; true ROI depends on *who fixes the tech when it breaks*. These efficiencies contribute directly to higher net margins and improved resource productivity.

When modeled over a typical 7–10 year investment horizon, studies have reported internal rates of return (IRRs) ranging between 12% and 25% for smart greenhouses in high-value horticulture sectors. However, these estimates often assume favorable conditions, such as low-cost financing, skilled labor availability, and consistent access to digital infrastructure. In developing countries, ROI can be significantly lower unless mitigated by public subsidies, concessional loans, or cooperative financing schemes.

A break-even analysis illustrates the importance of operational scale: commercial producers typically recover initial capital costs within 3–5 years, while smallholders may face 8–10 year breakeven periods unless supported by tailored policy

incentives. This highlights the need for differentiated economic models that account for farm size, financing mechanisms, and regional policy environments.

Indirect economic benefits must also be considered. These include increased crop quality and marketability due to more stable growing conditions, the ability to grow off-season or export-oriented crops, and reduced environmental compliance costs due to more efficient resource use. In export-driven agri-economies, AI-powered greenhouses can significantly improve product standardization, traceability, and certification—key factors in accessing premium markets.

However, high dependence on proprietary software and imported hardware components can increase system vulnerability and lifecycle costs. Maintenance requirements and technical downtimes can impose unforeseen costs, especially where local repair and support services are limited. A full cost-benefit framework must therefore include risk-adjusted net present value (NPV) assessments that incorporate uncertainty in market prices, input costs, and system durability.

In summary, while AI-driven smart greenhouses can deliver strong financial returns, especially in high-value or export-oriented farming systems, their viability depends on multiple contextual variables. Economies of scale, policy support, financing availability, and technological literacy all influence outcomes. Therefore, the cost-benefit calculus is not universally favorable, but rather contingent—requiring customized models to determine financial sustainability in diverse economic settings.

Market Viability and Scalability

The market viability of AI-driven smart greenhouses is closely linked to both technological diffusion and the structural characteristics of the agricultural sector. Globally, adoption trends reveal significant disparities: advanced economies such as the Netherlands, Japan, and Israel have demonstrated high penetration rates of smart greenhouse technologies, driven by export-oriented horticulture, government support, and strong agri-tech ecosystems. In contrast, adoption remains nascent in many developing countries, primarily due to limited infrastructure, access to finance, and policy support.

The scalability of these systems presents a dual challenge: economic and institutional. For large commercial producers, smart greenhouses offer scale advantages through labor savings, yield consistency, and export market access. These producers are better positioned to absorb upfront costs and deploy complementary technologies such as drones, blockchain, and renewable energy systems. For small and medium-sized enterprises (SMEs), however, scalability remains constrained by financial liquidity, digital literacy, and fragmented land holdings. Without aggregation models or cooperative investment frameworks, many SMEs remain priced out of the smart greenhouse market.

Market segmentation also plays a critical role. In premium food markets—such as organic vegetables, herbs, and high-value floriculture—AI-controlled environments can deliver substantial economic returns through quality differentiation and supply consistency. These segments are less price-sensitive and more innovation-driven, making them attractive entry points for smart greenhouse investments. Conversely, in

staple crop markets with thin margins and elastic demand, cost recovery is more challenging, limiting the appeal of capital-intensive technologies.

Export potential is another dimension of market viability. Countries with favorable agro-climatic conditions, low labor costs, and trade access can leverage AI-driven greenhouses to meet stringent phytosanitary and quality standards in international markets. Controlled-environment production enables year-round cultivation, reducing price volatility and increasing bargaining power in global value chains. In this context, AI technologies can act as strategic tools for improving competitiveness and ensuring compliance with sustainability standards, such as Global G.A.P. and organic certification.

Institutional factors, including access to rural broadband, extension services, and technical training, also determine the scalability of smart greenhouses. In many developing regions, lack of digital infrastructure and skilled labor inhibits effective deployment, even where the technology is technically feasible. This creates a market failure scenario that justifies targeted government intervention. Public-private partnerships, digital cooperatives, and incubator programs can play a catalytic role in extending smart greenhouse adoption beyond large-scale operations.

From a macroeconomic perspective, the broader adoption of AI in agriculture could contribute to structural transformation by raising productivity, enabling value-added exports, and generating employment in upstream sectors like agri-tech manufacturing and data analytics. However, for this potential to materialize, market access must be democratized through inclusive financing, modular system design, and supportive policy ecosystems.

In sum, market viability and scalability are not merely technological questions but are fundamentally shaped by economic incentives, institutional capacity, and policy architecture. Unlocking these technologies' full potential requires adaptive strategies that account for regional heterogeneity, sectoral structure, and the evolving dynamics of global agricultural trade.

Policy and Subsidy Landscape

The adoption of AI-driven smart greenhouses involves significant upfront capital expenditures and complex technical infrastructure, creating conditions of market failure that justify targeted public intervention. From a public economics perspective, these technologies generate positive externalities—such as resource conservation, reduced environmental degradation, and improved food security—that are not fully captured by private investors. As such, there is a compelling rationale for the use of corrective policy instruments to internalize these external benefits.

Governments in several countries have introduced subsidies, tax credits, and concessional loans to incentivize investment in smart agriculture technologies. These incentives are increasingly aligned with Environmental, Social, and Governance (ESG) principles, reflecting broader sustainability goals and commitments under national climate strategies. For instance, capital subsidies can offset the initial cost burden, while tax incentives tied to digital transformation or energy efficiency can improve the medium-term financial returns for adopters.

However, the effectiveness of these instruments depends on their design and targeting. Blanket subsidies may encourage inefficiencies or lead to technology uptake in contexts where it is not economically sustainable. Therefore, outcome-based subsidies—linked to verified improvements in resource use efficiency, yield, or carbon footprint reduction—can offer a more efficient allocation of public funds. Moreover, the availability of subsidies should be complemented by accessible financing channels, particularly for SMEs, through agricultural banks, microfinance institutions, or digital lending platforms.

Public-private partnerships (PPPs) represent another strategic policy tool. Governments can de-risk private investment through co-financing arrangements, infrastructure sharing, or technology pilots that demonstrate economic feasibility. PPPs can also foster the development of open-source AI platforms, reducing dependence on costly proprietary systems and enhancing interoperability across regions. Similarly, government-supported innovation hubs and incubators can help localize technology development, train a new generation of agri-tech entrepreneurs, and stimulate job creation.

Beyond fiscal measures, regulatory frameworks play a critical role in enabling market adoption. These include data governance policies to ensure ownership, privacy, and transparency in AI systems; intellectual property protections that encourage innovation without monopolizing access; and standards for greenhouse certification to facilitate access to export markets. Institutional investment in digital infrastructure—such as broadband connectivity, IoT platforms, and cloud computing access—is also foundational to AI deployment in rural areas.

Importantly, the policy environment must balance efficiency and equity. Without inclusive design, subsidies and infrastructure may disproportionately benefit large agribusinesses while excluding smallholders and marginal producers. Tiered subsidy structures, cooperative purchasing models, and targeted extension services can help ensure that the benefits of AI technologies are equitably distributed.

In sum, a well-designed policy and subsidy landscape is essential for overcoming the structural barriers to smart greenhouse adoption. By leveraging a combination of fiscal, regulatory, and institutional tools, governments can foster a more efficient, equitable, and sustainable agricultural transformation. Effective policy coordination across ministries of agriculture, finance, environment, and digital development will be critical in realizing the full economic potential of AI in agriculture.

Barriers to Adoption and Strategies for Mitigation

Despite the technological promise and economic potential of AI-driven smart greenhouses, several structural and institutional barriers continue to constrain widespread adoption. These barriers can be broadly categorized into financial, technical, institutional, and behavioral dimensions—each of which carries distinct policy implications.

1. Financial Barriers The most commonly cited challenge is the high upfront capital investment required for AI infrastructure, including sensors, data systems, control hardware, and software subscriptions. For many farmers—particularly smallholders and SMEs—liquidity constraints and limited access to affordable

credit inhibit investment. This is exacerbated by a lack of collateral and credit history, making it difficult to secure bank financing. In economic terms, this represents a capital market imperfection, where potentially high-return investments remain unfunded due to financing frictions.

Mitigation Strategy: Governments and development institutions can address this through targeted loan guarantees, low-interest credit schemes, or blended finance models that reduce the risk borne by private lenders. Risk-sharing mechanisms, such as agricultural insurance tied to AI-adoption outcomes, can also improve creditworthiness.

2. Technical and Infrastructure Constraints

Effective deployment of AI systems requires reliable electricity, internet connectivity, and sensor calibration infrastructure—resources that are often lacking in rural or low-income regions. Additionally, interoperability challenges between legacy systems and new platforms can raise integration costs and create technological lock-in. Mitigation Strategy: Investment in rural digital infrastructure is critical. Governments can incentivize telecom expansion into underserved areas and fund open-source software development to reduce vendor lock-in. International donors and climate finance mechanisms may also play a role in scaling infrastructure for agri-tech adoption.

3. Human Capital and Knowledge Gaps

AI systems demand a minimum level of digital literacy, data interpretation skills, and technical maintenance know-how—competencies that are scarce in many agricultural regions. The labor market mismatch between technological demands and available skills slows adoption and may lead to underutilization of installed systems. Mitigation Strategy: Human capital investment is essential. Vocational training programs, agricultural extension services, and digital literacy campaigns can build farmer capacity. Partnerships with universities and agri-tech firms to develop modular, user-friendly interfaces can also reduce the learning curve.

4. Behavioral and Institutional Resistance. Even where the economic case for adoption is strong, behavioral factors—such as resistance to change, risk aversion, or mistrust in digital systems—can act as significant barriers. Farmers may also face information asymmetries, not fully understanding the potential returns or operational requirements of AI systems.

Mitigation Strategy: Demonstration farms, peer learning programs, and pilot subsidies can reduce uncertainty and build trust. Behavioral nudges, such as information framing and early adopter testimonials, have proven effective in other agricultural technology contexts and may accelerate AI uptake.

5. Ethical, Regulatory, and Data Governance Challenges. Concerns over data privacy, algorithmic transparency, and ownership rights can deter adoption, especially in areas where legal frameworks are weak or poorly enforced. These issues are particularly salient as AI expands its role in decision-making.

Mitigation Strategy: Clear regulatory standards on data ownership, privacy, and ethical AI use are essential. Governments must work with stakeholders to develop fair, transparent, and enforceable digital governance frameworks. Inclusion of farmers in data governance discussions can improve adoption and trust.

In sum, addressing the adoption gap requires a multi-pronged strategy that aligns economic incentives, strengthens institutional capacity, and reduces behavioral and informational frictions. A coordinated effort across governments, financial institutions, tech developers, and educational bodies is essential to democratize access to AI in agriculture and unlock its full economic potential.

Literature Review

A growing body of literature has documented the transformative role of AI and digital technologies in agriculture, especially in enhancing productivity, sustainability, and resource efficiency (Assimakopoulos et al., 2025; Gikunda, 2024). Precision agriculture—driven by sensor networks, machine learning, and automation—has enabled farmers to optimize input use and improve crop yields. Smart greenhouses represent a focused application of these technologies, offering controlled environments for intensive crop production. However, much of the existing literature emphasizes technological feasibility rather than economic viability.

From an economic standpoint, smart greenhouses are characterized by high upfront capital costs, but also by potentially significant operational savings. Al-Qudah et al. (2024) highlight the ability of AI algorithms to improve water and fertilizer efficiency, reducing variable costs over time. Khanna et al. (2024) argue that while digital technologies may be economically justified in large-scale operations, their financial appeal to smallholders and SMEs remains limited without targeted policy support. This raises questions of equity and access in the diffusion of smart agricultural technologies.

Another key theme in the literature is the role of data availability and analytics in enabling decision-making. Data-rich environments enhance productivity, but gathering and processing agricultural data can be cost-prohibitive, especially for SMEs (Eyeregba et al., 2024). Moreover, compatibility issues between legacy infrastructure and new AI platforms pose integration challenges (Guevara et al., 2024). These factors contribute to what Iyelolu et al. (2024) describe as a 'digital divide' in AI adoption across regions and farm sizes.

Policy interventions are increasingly recognized as essential for addressing these barriers. Studies by Dara et al. (2022) and Saheb & Dehghani (2021) emphasize the importance of ESG-aligned incentives, digital infrastructure development, and ethical AI governance in agricultural contexts. However, there is limited research on the effectiveness of specific economic instruments—such as subsidies, tax relief, or concessional loans—in enhancing ROI and accelerating adoption. This review seeks to fill that gap by examining how economic policy can bridge technological and financial constraints.

In summary, while the literature affirms the agronomic and environmental potential of AI-driven greenhouses, economic analyses remain fragmented. This review contributes by synthesizing cost-benefit evidence, evaluating market readiness, and assessing the alignment of policy instruments with investment viability. In doing so, it offers a structured economic perspective on smart greenhouse deployment, with implications for researchers, practitioners, and policymakers.

METHODOLOGY

This review adopts a structured narrative synthesis methodology, integrating both qualitative insights and quantitative evidence to evaluate the economic viability of AI-driven smart greenhouses. The goal is to develop a coherent understanding of cost structures, return on investment (ROI), market feasibility, and policy implications associated with these technologies. This approach is particularly suited to interdisciplinary topics where empirical findings are scattered across technological, agronomic, and economic domains.

The literature search covered peer-reviewed journal articles, conference proceedings, industry white papers, and policy reports published between 2010 and early 2025. Searches were conducted using major academic databases—such as Scopus, Web of Science, ScienceDirect, JSTOR, and Google Scholar—along with selected institutional repositories (e.g., FAO, OECD, World Bank, and IFPRI). Key search terms included: "AI in agriculture," "smart greenhouses," "economic impact of digital farming," "agriculture ROI," "adoption barriers in agri-tech," and "policy incentives for sustainable farming." Boolean operators and citation chaining were employed to ensure breadth and depth.

Inclusion criteria focused on studies that addressed at least one of the following economic dimensions: capital and operational cost analysis, economic return estimates, market scalability, policy incentives, or barriers to technology adoption. Studies purely focused on technical implementation without any economic data or implications were excluded unless they contributed to broader economic analysis through case applications. Grey literature, particularly from international development agencies and agri-tech startups, was included where it offered credible cost-benefit insights or policy evaluations.

The selected literature was analyzed through a thematic synthesis framework, organized across five main analytical dimensions:

Cost structures and investment efficiency – examining capital costs, operational savings, and ROI calculations.

Market viability and scalability – evaluating adoption rates, export potential, and financial accessibility for SMEs.

Barriers to adoption – including high capital costs, digital illiteracy, infrastructure deficits, and behavioral resistance.

Policy and subsidy landscape – assessing how economic instruments (e.g., subsidies, tax credits, ESG-aligned investments) impact adoption and investment behavior.

Ethical and institutional considerations – such as data privacy, algorithmic fairness, and equity in technology access.

To strengthen the economic focus, case studies with quantifiable financial outcomes were prioritized. Where available, numeric data on input use reduction, productivity gains, breakeven points, and net present value (NPV) were extracted and compared. Regional heterogeneity was addressed by categorizing studies into developed and developing country contexts. Cross-case comparisons were used to

assess generalizability of findings and to identify context-specific drivers of economic performance.

This methodological strategy allows for a comprehensive and policy-relevant synthesis that bridges the gap between agronomic promise and economic practicality. By grounding the analysis in both theoretical and empirical perspectives from agricultural economics and innovation policy, the review aims to support more informed decision-making by policymakers, investors, and development agencies. The approach also highlights areas for future empirical research, particularly in underrepresented regions where economic data on digital agriculture remains sparse.

RESULTS

AI-driven smart greenhouses offer compelling economic advantages through reduced resource use, labor efficiency, and enhanced crop yields, making them increasingly attractive investments in both developed and developing economies.

Discussion

This review highlights that while AI-driven smart greenhouses present a compelling technological innovation in agriculture, their economic viability is highly contingent on contextual factors. The balance between high capital intensity and long-term operational efficiency creates a differentiated adoption landscape, favoring commercial and export-oriented producers unless proactive policy measures are implemented. These dynamics reflect broader patterns of technological diffusion, capital concentration, and market segmentation commonly observed in emerging digital sectors.

From an economic theory perspective, the findings suggest that AI-enabled agriculture—particularly smart greenhouses—embody both public good characteristics and externalities. Benefits such as resource efficiency, environmental sustainability, and improved food security are not fully internalized by individual producers, creating a rationale for policy intervention through subsidies, infrastructure investment, or regulatory reform. The deployment of targeted economic instruments can thus address underinvestment and encourage socially optimal adoption.

Importantly, the paper reveals that the economic feasibility of smart greenhouses is not a fixed attribute, but rather an outcome shaped by a triad of factors: market incentives, institutional readiness, and policy architecture. Where supportive ecosystems exist—featuring access to finance, skilled labor, and digital infrastructure—AI systems can offer strong returns on investment. In their absence, even the most promising technologies may remain economically inaccessible. This underlines the importance of a systems-thinking approach in economic policy design, where technology, institutions, and behavior are co-optimized.

Furthermore, the evidence synthesized suggests that the benefits of AI adoption may not be evenly distributed. Without specific safeguards and inclusion strategies, smaller farms and marginalized regions may be left behind—exacerbating existing inequalities in access to capital, knowledge, and market opportunities. This has critical implications for sustainable development policy, requiring subsidy structures and digital infrastructure strategies that explicitly incorporate equity considerations.

The review also reveals areas of uncertainty and emerging risk. For instance, the durability and lifecycle costs of AI hardware in harsh agricultural environments remain poorly documented. Similarly, data governance and cybersecurity are nascent but increasingly important dimensions of agricultural digitalization. Future research should examine how contractual arrangements, platform regulation, and cooperative data ownership models can shape the economic sustainability of smart farming ecosystems.

In terms of broader macroeconomic impacts, the adoption of smart greenhouses has the potential to contribute to structural transformation—shifting agricultural production from low-productivity, labor-intensive systems toward high-efficiency, knowledge-intensive operations. This transformation could stimulate growth in related sectors such as software development, renewable energy, sensor manufacturing, and agricultural finance. However, realizing this potential depends on the strategic alignment of industrial, environmental, and innovation policy.

IN CONCLUSION

The economic potential of AI-driven smart greenhouses is substantial but remains highly path-dependent. It requires carefully designed interventions that not only reduce adoption barriers but also promote inclusive innovation. For policymakers, the challenge lies not only in accelerating technology adoption but in ensuring that its benefits are equitably distributed and institutionally embedded. For researchers, future work should focus on region-specific cost-effectiveness analysis, behavioral adoption modeling, and the role of governance in shaping digital agriculture markets.

Conclusion. This review has examined the economic case for AI-driven smart greenhouses through the lenses of cost-efficiency, market viability, and policy design. While the agronomic and technological dimensions of smart agriculture are well documented, this paper highlights that the economic feasibility of such systems is more context-specific and shaped by financial, institutional, and policy environments.

The findings show that smart greenhouses can deliver compelling economic returns—particularly in high-value crop markets and export-oriented contexts—by reducing input costs, improving labor productivity, and stabilizing yields. However, high capital requirements and operational complexity present substantial barriers, especially for smallholder farmers and emerging economies. Addressing these barriers requires an integrated policy framework that combines targeted subsidies, inclusive financing mechanisms, capacity-building programs, and investments in rural digital infrastructure.

Importantly, the analysis underscores that policy interventions must go beyond generic support and move toward precision targeting: outcome-based subsidies, cooperative financing models, and incentives tied to ESG outcomes offer more efficient and equitable pathways to adoption. Similarly, regulatory frameworks on data governance, AI ethics, and platform interoperability are essential to support sustainable scaling.

The broader economic potential of smart greenhouses lies not only in their productivity gains but in their role as catalysts for agricultural transformation. They

offer a pathway toward climate-smart, tech-enabled, and export-competitive food systems—provided that the right enabling conditions are in place.

For policymakers, the challenge is to design ecosystems that align private incentives with public goals. For investors and entrepreneurs, the opportunity lies in developing scalable, affordable solutions tailored to diverse regional markets. For researchers, a future agenda includes detailed cost-effectiveness modeling, behavioral analysis of adoption, and exploration of digital public goods in agriculture.

In conclusion, while AI-powered smart greenhouses are not a universal solution, they represent a high-potential innovation whose economic viability can be unlocked through smart policy, inclusive finance, and institutional innovation. Their successful integration into agri-food systems could significantly reshape the economics of sustainable agriculture in the 21st century.

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FERMER XO‘JALIKLARIDA RISKLARNI BOSHQARISH

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Annotatsiya*: Maqolada fermer xo‘jaliklarida risklarni boshqarish tizimining ahamiyati va uning qishloq xo‘jaligi ishlab chiqarish samaradorligiga ta’siri tahlil qilinadi. Qishloq xo‘jaligi faoliyati tabiiy-iqlim sharoitlari, bozor narxlarining o‘zgaruvchanligi, moliyaviy cheklovlar hamda institutsional omillar bilan chambarchas bog‘liq bo‘lib, bu holatlar yuqori darajadagi risklarni yuzaga keltiradi. Tadqiqot davomida risklarning asosiy turlari aniqlanib, ularni boshqarishning zamonaviy usullari va strategiyalari o‘rganildi. Shuningdek, risklarni kamaytirishda diversifikatsiya, sug‘urta mexanizmlari, innovatsion texnologiyalar va davlat tomonidan qo‘llab-quvvatlash choralarining o‘rni yoritib berildi. Tadqiqot natijalari fermer xo‘jaliklarida barqaror rivojlanishni ta’minlash va boshqaruv qarorlarini takomillashtirishda amaliy ahamiyatga ega.*

Kalit sozi: *Qishloq xo‘jaligi risklari; risklarni boshqarish; fermer xo‘jaliklari; iqlim o‘zgarishi; bozor beqarorligi; diversifikatsiya; sug‘urta mexanizmlari; moliyaviy risklar; innovatsion texnologiyalar; risk tahlili.*

Аннотация: *В статье анализируется важность системы управления рисками в сельском хозяйстве и ее влияние на эффективность сельскохозяйственного производства. Сельскохозяйственная деятельность тесно связана с природными и климатическими условиями, волатильностью рыночных цен, финансовыми ограничениями и институциональными факторами, что создает высокий уровень рисков. В ходе исследования были определены основные виды рисков и изучены современные методы и стратегии их управления. Также была подчеркнута роль диверсификации, механизмов страхования, инновационных технологий и мер государственной поддержки в снижении рисков. Результаты исследования имеют практическое значение для обеспечения устойчивого развития сельского хозяйства и совершенствования управленческих решений.*

Ключевые слова: *Сельскохозяйственные риски; управление рисками; сельское хозяйство; изменение климата; нестабильность рынка; диверсификация; механизмы страхования; финансовые риски; инновационные технологии; анализ рисков.*

Abstract: *The article analyzes the importance of the risk management system in farms and its impact on the efficiency of agricultural production. Agricultural activities are closely related to natural and climatic conditions, market price volatility, financial constraints, and institutional factors, which create a high level of risks. During the study, the main types of risks were identified and modern methods and strategies for their management were studied. The role of diversification, insurance mechanisms, innovative technologies, and state support measures in reducing risks was also highlighted. The results of the study are of practical importance in ensuring sustainable development in farms and improving management decisions.*

Keywords: *Agricultural risks; risk management; farms; climate change; market instability; diversification; insurance mechanisms; financial risks; innovative technologies; risk analysis.*

KIRISH

Qishloq xo‘jaligi iqtisodiy taraqqiyotning eng asosiy tarmoqlaridan biri bo‘lib, mamlakatning oziq-ovqat xavfsizligi, eksport salohiyati va hududiy ijtimoiy barqarorligiga bevosita ta’sir ko‘rsatadi. Ushbu soha tabiiy-iqlim sharoitlariga kuchli bog‘liqligi, bozor narxlarining o‘zgaruvchanligi, ishlab chiqarish jarayonidagi texnik va texnologik cheklovlar, mehnat resurslari yetishmovchiligi kabi omillar tufayli yuqori darajadagi risklarga ega. Shuning uchun fermer xo‘jaliklarida risklarni to‘g‘ri boshqarish samaradorlikni oshirish, barqaror ishlab chiqarish tizimini shakllantirish hamda agrar sohada uzoq muddatli rivojlanishni ta’minlashning muhim omili hisoblanadi. Fermer xo‘jaliklari faoliyatida risklar ko‘p qirrali bo‘lib, ular ishlab chiqarish, bozor, moliyaviy, institutsional va ekologik risklarga bo‘linadi. Ishlab chiqarish risklariga hosildorlikning pasayishi, qurg‘oqchilik, ortiqcha yog‘ingarchilik, zararkunandalar va kasalliklar kiradi. Bozor risklari esa mahsulot narxining keskin o‘zgarishi, talabning pasayishi yoki eksport cheklovlari bilan bog‘liq. Moliyaviy risklar kredit ololmaslik, foiz stavkalarining oshishi yoki likvidlikning yetarli emasligi orqali namoyon bo‘ladi. Bunday xavfli sharoitlarda fermer xo‘jaliklari o‘z resurslarini oqilona taqsimlashi, modernizatsiya va texnologik yangiliklarni joriy qilishi, mavjud bozor imkoniyatlaridan samarali foydalanishi zarur. So‘nggi yillarda global miqyosda iqlim o‘zgarishi qishloq xo‘jaligi ishlab chiqarishidagi eng keskin xavf omillaridan biriga aylandi. Mutaxassislarning ta’kidlashicha, iqlimning isishi, suv tanqisligi, ekstremal ob-havo hodisalari ko‘payishi hosildorlik barqarorligini xavf ostiga qo‘ymoqda. Bu esa risklarni boshqarish strategiyalarini yanada ilmiy asosda takomillashtirishni taqozo etadi. Shu nuqtai nazardan qaraganda, zamonaviy diversifikatsiya choralari, raqamli monitoring tizimlari, agrotexnik innovatsiyalar, tomchilatib sug‘orish kabi resurs tejamkor texnologiyalar risklarni sezilarli darajada kamaytirishi mumkin. Fermer xo‘jaliklarida risklarni boshqarish nafaqat ishlab chiqarish barqarorligini ta’minlaydi, balki iqtisodiy foydani oshirish, xarajatlarni optimallashtirish, bozor sharoitlariga moslashish va qaror qabul qilish jarayonini tezlashtirish imkonini beradi. Masalan, diversifikatsiya orqali turli ekinlarni yetishtirish yoki chorvachilikni qo‘shma rivojlantirish fermer xo‘jaligini bozordagi narx tebranishlaridan himoyalaydi. Sug‘urta mexanizmlari esa noqulay ob-havo yoki

tabiiy ofatlar oqibatida ko‘riladigan zararni qisman qoplaydi. Bunday mexanizmlardan foydalanish agrar tarmoqning barqarorligini mustahkamlovchi omil sifatida muhim ahamiyatga ega. Davlat tomonidan risklarni kamaytirishga qaratilgan chora-tadbirlar ham muhim o‘rin tutadi. Agrar sohada kreditlar bo‘yicha imtiyozlar, subsidiyalar, davlat sug‘urtasi tizimlari, agrologistika markazlarining tashkil etilishi fermer xo‘jaliklarining xavf sharoitidagi barqarorligini oshirib boradi. Shuningdek, xalqaro moliya institutlari tomonidan moliyalashtirilayotgan iqlimga moslashuv dasturlari, suvni boshqarish loyihalari va ekologik barqaror texnologiyalarni joriy etish tashabbuslari risklarni boshqarishda qo‘shimcha imkoniyatlar yaratmoqda. Ushbu tadqiqotning dolzarbligi shundan iboratki, O‘zbekiston sharoitida fermer xo‘jaliklarida risklarni boshqarish bo‘yicha ilmiy asoslangan yondashuvlar hali ham to‘liq rivojlanmagan. Shuning uchun maqola fermer xo‘jaliklarida risklarning asosiy turlarini aniqlash, ularni boshqarishning samarali usullarini taklif etish va amaliyotda qo‘llash mumkin bo‘lgan mexanizmlarni o‘rganishga qaratiladi. Tadqiqot natijalari fermer xo‘jaliklarida barqaror ishlab chiqarishni ta’minlash, iqtisodiy samaradorlikni oshirish va risklarni kamaytirish sohasida nazariy hamda amaliy asoslarni mustahkamlashga xizmat qiladi.

TADQIQOT METODOLOGIYASI

Ushbu tadqiqot fermer xo‘jaliklarida risklarni boshqarish tizimini tahlil qilish va uning ishlab chiqarish samaradorligiga ta’sirini aniqlashga qaratilgan bo‘lib, tadqiqot jarayonida kompleks ilmiy-uslubiy yondashuvlardan foydalanildi. Metodologiya nazariy tahlil, empirik kuzatuvlar, taqqoslash, statistik tahlil hamda mantiqiy umumlashtirish usullariga asoslandi. Tadqiqot dizayni fermer xo‘jaliklari faoliyatida uchraydigan risk turlarini aniqlash, ularning ta’sir darajasini baholash va risklarni kamaytirishga qaratilgan boshqaruv strategiyalarining samaradorligini o‘rganishga yo‘naltirildi. Tadqiqotning birinchi bosqichida risklarni boshqarish bo‘yicha mavjud ilmiy adabiyotlar, milliy va xalqaro tajribalar, normativ-huquqiy hujjatlar tahlil qilindi. Ushbu nazariy tahlil orqali qishloq xo‘jaligida risk tushunchasi, risk turlari va ularni boshqarish yondashuvlari aniqlashtirildi. Adabiyotlar sharhi risklarni ishlab chiqarish, bozor, moliyaviy, institutsional va ekologik guruhlarga ajratish imkonini berdi. Bu tasnif tadqiqotning keyingi bosqichlarida empirik tahlil uchun metodologik asos bo‘lib xizmat qildi. Tadqiqotning ikkinchi bosqichida empirik ma’lumotlar yig‘ish usullari qo‘llanildi. Bunda fermer xo‘jaliklarining ishlab chiqarish hajmi, ekin turlari, hosildorlik darajasi, xarajatlar tarkibi va daromad ko‘rsatkichlari bo‘yicha ochiq statistik ma’lumotlar o‘rganildi. Shuningdek, risk omillarining fermer xo‘jaliklari faoliyatiga ta’sirini aniqlash maqsadida so‘rovnoma va kuzatuv usullaridan foydalanildi. So‘rovnomalar fermerlarning iqlim sharoiti, bozor narxlari, moliyaviy resurslarga kirish imkoniyati va sug‘urta mexanizmlaridan foydalanish darajasi bo‘yicha fikrlarini aniqlashga qaratildi. Uchinchi bosqichda risklarni baholash va tahlil qilish amalga oshirildi. Risk tahlili ehtimollik va ta’sir darajasi asosida olib borildi. Bunda har bir risk turi fermer xo‘jaligi faoliyatiga qanchalik salbiy ta’sir ko‘rsatishi aniqlanib, ularning ustuvorlik darajasi belgilandi. Ushbu yondashuv risklarni yuqori, o‘rta va past darajali guruhlarga ajratish imkonini berdi. Natijada fermer xo‘jaliklari

uchun eng xavfli risklar aniqlanib, ularni kamaytirishga qaratilgan strategiyalar ishlab chiqildi. Tadqiqot jarayonida statistik tahlil usullaridan ham foydalanildi. Hosildorlik va daromad ko‘rsatkichlarining yillik o‘zgarishi risk omillari bilan taqqoslanib, ularning o‘zaro bog‘liqligi tahlil qilindi. Taqqoslash usuli orqali risklarni boshqarish choralarini qo‘llagan fermer xo‘jaliklari bilan bunday choralarni yetarli darajada amalga oshirmagan xo‘jaliklar o‘rtasidagi farqlar aniqlandi. Bu esa risklarni boshqarishning iqtisodiy samaradorligini baholash imkonini berdi. Tadqiqotning to‘rtinchi bosqichida risklarni boshqarish strategiyalarining samaradorligi tahlil qilindi. Diversifikatsiya, sug‘urta mexanizmlaridan foydalanish, resurs tejamkor texnologiyalarni joriy etish va moliyaviy rejalashtirish kabi usullarning risklarni kamaytirishdagi o‘rni baholandi. Har bir strategiya fermer xo‘jaliklarining barqarorligi va daromadliligiga ta’siri nuqtai nazaridan ko‘rib chiqildi. Ushbu tahlil asosida risklarni boshqarish bo‘yicha amaliy tavsiyalar ishlab chiqildi. Metodologiyaning yakuniy bosqichida olingan natijalar umumlashtirildi va mantiqiy xulosalar chiqarildi. Tadqiqot davomida qo‘llanilgan usullar fermer xo‘jaliklarida risklarni boshqarish tizimini kompleks baholash imkonini berdi hamda maqolaning keyingi bo‘limlarida keltiriladigan natijalar va muhokamalar uchun mustahkam ilmiy asos yaratdi. Ushbu metodologik yondashuv tadqiqot natijalarining ishonchliligi va amaliy ahamiyatini ta’minlashga xizmat qiladi.

TADQIQOT NATIJALARI

Fermer xo‘jaliklarida uchraydigan asosiy risk turlari, ularning ishlab chiqarish samaradorligiga ta’siri hamda risklarni boshqarish strategiyalarining iqtisodiy natijalari tahlil qilinadi. Tadqiqot natijalari jadval va diagrammalar asosida tizimli ravishda bayon etildi.

1-jadval

Fermer xo‘jaliklarida uchraydigan asosiy risk turlari va ularning ta’sir darajasi

Risk turlari	Risk manbai	Ta’sir darajasi
Ishlab chiqarish riski	Iqlim, kasallik, zararkunanda	Yuqori
Bozor riski	Narxlarning o‘zgarishi	Yuqori
Moliyaviy risk	Kredit va likvidlik muammolari	O‘rta
Institutsional risk	Qonunchilik va siyosiy omillar	O‘rta
Ekologik risk	Suv tanqisligi, tuproq degradatsiyasi	Yuqori

Jadval ma’lumotlaridan ko‘rinib turibdiki, fermer xo‘jaliklari faoliyatiga eng kuchli ta’sir ko‘rsatuvchi risklar ishlab chiqarish, bozor va ekologik risklar hisoblanadi. Ayniqsa, iqlim sharoitlari va suv resurslari bilan bog‘liq omillar ishlab chiqarish barqarorligini izdan chiqaruvchi asosiy xavf manbai sifatida namoyon bo‘lmoqda. Bu holat fermer xo‘jaliklarida risklarni boshqarish strategiyalarini ishlab chiqishda ekologik va iqlimiy omillarga ustuvor ahamiyat berish zarurligini ko‘rsatadi.

2-jadval

Risklarni boshqarish strategiyalarining fermer xo‘jaliklari daromadiga ta’siri

Boshqaruv strategiyasi	O‘rtacha daromad o‘zgarishi (%)
Diversifikatsiya	+18
Sug‘urta mexanizmlaridan foydalanish	+12
Resurs tejamkor texnologiyalar	+22
Moliyaviy rejalashtirish	+10

Ushbu jadvaldan ko‘rinib turibdiki, risklarni boshqarish strategiyalarini qo‘llagan fermer xo‘jaliklarida daromad sezilarli darajada oshgan. Ayniqsa, resurs tejamkor texnologiyalarni joriy etish daromadning 22 foizga oshishiga olib kelgan. Bu natija innovatsion texnologiyalar risklarni kamaytirish bilan birga ishlab chiqarish samaradorligini ham oshirishini tasdiqlaydi. Diversifikatsiya va sug‘urta mexanizmlari esa bozor va iqlim risklariga qarshi muhim himoya vositasi sifatida namoyon bo‘lmoqda.

3-jadval

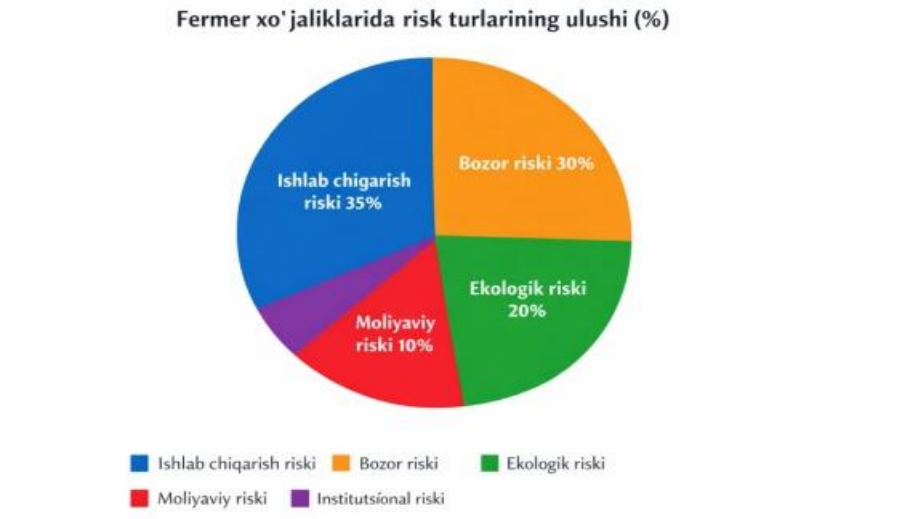
Risklarni boshqarish darajasiga qarab fermer xo‘jaliklarining barqarorligi

Risklarni boshqarish darajasi	Hosildorlik barqarorligi
Past	Past
O‘rta	O‘rta
Yuqori	Yuqori

Jadval natijalari risklarni boshqarish darajasi bilan hosildorlik barqarorligi o‘rtasida bevosita bog‘liqlik mavjudligini ko‘rsatadi. Risklarni samarali boshqarayotgan fermer xo‘jaliklarida hosildorlik barqarorroq bo‘lib, tashqi salbiy omillarning ta’siri sezilarli darajada kamaygan. Bu holat risklarni boshqarish tizimini mustahkamlash fermer xo‘jaliklarining uzoq muddatli barqaror rivojlanishini ta’minlashini isbotlaydi.

1-diagramma

Fermer xo‘jaliklarida risk turlarining ulushi (%)



Diagrammadan ko‘rinib turibdiki, fermer xo‘jaliklarida eng katta ulushni ishlab chiqarish va bozor risklari egallaydi. Bu ikki risk turi umumiy xavflarning 65 foizini tashkil etadi. Ekologik risklar ham muhim ulushga ega bo‘lib, suv tanqisligi va tuproq degradatsiyasi bilan bog‘liq muammolar fermer xo‘jaliklari faoliyatiga kuchli ta’sir ko‘rsatmoqda. Moliyaviy va institutsional risklar nisbatan kamroq ulushga ega bo‘lsa-da, ular boshqarilmagan taqdirda ishlab chiqarish samaradorligiga jiddiy salbiy ta’sir ko‘rsatishi mumkin.

Tadqiqot natijalari fermer xo‘jaliklarida risklarni boshqarish ishlab chiqarish barqarorligi va iqtisodiy samaradorlikka sezilarli ta’sir ko‘rsatishini ko‘rsatdi. Avvalo, ishlab chiqarish risklarining eng yuqori ulushga ega ekani aniqlandi. Bu qishloq xo‘jaligining iqlim va ekologik sharoitlarga bevosita bog‘liqligi bilan izohlanadi. Qurg‘oqchilik, keskin harorat o‘zgarishi va zararkunandalar fermerlar uchun asosiy xavf bo‘lib qolmoqda. Bozor risklari ulushining yuqoriligi esa narxlarning beqarorligi, bozor infratuzilmalarining yetarli rivojlanmagani va sotuv kanallari cheklanganligi bilan bog‘liq. Ekologik risklar suv tanqisligi va tuproq degradatsiyasi tufayli hosildorlikka kuchli salbiy ta’sir ko‘rsatmoqda. Tadqiqot shuni ko‘rsatdiki, resurs tejamkor texnologiyalar (tomchilatib sug‘orish, agrotexnik innovatsiyalar) ekologik risklarni kamaytirishda eng samarali vositalardan biridir. Moliyaviy va institutsional risklar ulushi nisbatan past bo‘lsa-da, ularning fermer xo‘jaliklari barqarorligiga ta’siri yetarlicha sezilarli. Ayniqsa, sug‘urta tizimidan foydalanish darajasi past bo‘lgani uchun ko‘plab xo‘jaliklar kutilmagan zararlarni o‘z vaqtida qoplay olmayapti. Jadval natijalari risklarni boshqarish strategiyalarini qo‘llagan fermerlarda daromad o‘sishi yuqori ekanini tasdiqladi. Resurs tejamkor texnologiyalar 22 foizgacha daromad oshishini ta’minlagan bo‘lsa, diversifikatsiya va sug‘urta ham barqarorlikni mustahkamlashga xizmat qilgan. Shuningdek, risklarni boshqarish darajasi yuqori bo‘lgan xo‘jaliklarda hosildorlikning barqarorligi ham aniq sezilgan. Umuman olganda, risklarni samarali boshqarish fermer xo‘jaliklarining uzoq muddatli barqaror rivojlanishining asosiy omillaridan biri ekanini ko‘rsatadi.

XULOSA

Ushbu tadqiqot fermer xo‘jaliklarida risklarni boshqarish tizimi qishloq xo‘jaligi ishlab chiqarishining barqarorligini ta’minlashda qanday ahamiyatga ega ekanini chuqur yoritib berdi. Olingan natijalar shuni ko‘rsatadiki, fermer xo‘jaliklari eng ko‘p duch keladigan xavflar — ishlab chiqarish, bozor va ekologik risklardir. Bu risklarning yuqori ulushi qishloq xo‘jaligining tabiiy-iqlim sharoitlariga kuchli bog‘liqligi, narxlarning bozor kon’yunkturasiga ko‘ra tez o‘zgarishi hamda suv va tuproq resurslari bilan bog‘liq muammolar mavjudligi bilan izohlanadi. Tadqiqot shuni tasdiqladiki, risklarni samarali boshqarish orqali hosildorlik va daromad barqarorligini sezilarli darajada oshirish mumkin. Xususan, resurs tejamkor texnologiyalarni joriy etish, diversifikatsiya, sug‘urta mexanizmlaridan foydalanish va moliyaviy rejalashtirish fermer xo‘jaliklarining umumiy iqtisodiy ko‘rsatkichlariga ijobiy ta’sir ko‘rsatmoqda. Jadval va diagramma tahlillari ushbu strategiyalarning natijadorligi bo‘yicha aniq dalillarni taqdim etdi. Shuningdek, risklarni boshqarish darajasining yuqoriligi hosildorlik barqarorligi bilan bevosita bog‘liq ekani aniqlandi. Bu esa risklarni

boshqarish jarayoniga tizimli yondashuv, ilmiy asoslangan qarorlar va innovatsion texnologiyalardan foydalanish zarurligini ko‘rsatadi. Umuman olganda, tadqiqot natijalari fermer xo‘jaliklarida risklarni boshqarish faqat muammolarni bartaraf etish vositasi emas, balki raqobatbardoshlikni oshirish, iqtisodiy barqarorlikni mustahkamlash va uzoq muddatli rivojlanishni ta’minlashning asosiy omili ekanini isbotlaydi.

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STARTAP LOYIHALARIDA MARKETING MENEJMENT STRATEGIYALARINI SHAKLLANTIRISH

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Annotatsiya*: Maqolada startap loyihalarida marketing menejment strategiyalarini shakllantirish masalalari va ularning biznesni barqaror rivojlantirishdagi ahamiyati tahlil qilinadi. Zamonaviy raqamli iqtisodiyot sharoitida startaplar kuchli raqobat va cheklangan resurslar bilan faoliyat yuritadi, bu esa samarali marketing boshqaruvini muhim omilga aylantiradi. Tadqiqotda startaplarda qo‘llaniladigan asosiy marketing strategiyalari, jumladan bozorni tahlil qilish, maqsadli auditoriyani aniqlash, brendni joylashtirish hamda raqamli marketing vositalaridan foydalanish masalalari ko‘rib chiqiladi. Shuningdek, startaplarning mijozlar va investorlarni jalb etishiga yordam beruvchi innovatsion marketing yondashuvlari o‘rganiladi. Tadqiqot natijalari samarali marketing strategiyasi startap loyihalarining raqobatbardoshligini oshirish va ularning barqaror rivojlanishini ta’minlashda muhim ahamiyatga ega ekanligini ko‘rsatadi.*

Kalit sozi: *Startap, marketing menejmenti, marketing strategiyasi, raqamli marketing, innovatsion biznes, bozor tahlili.*

Аннотация*: В данной статье рассматриваются вопросы формирования стратегий маркетингового менеджмента в стартап-проектах и их роль в обеспечении устойчивого развития бизнеса. В условиях современной цифровой экономики стартапы сталкиваются с высокой конкуренцией и ограниченными ресурсами, что делает эффективное управление маркетингом важным фактором успеха. В исследовании анализируются основные маркетинговые стратегии, используемые в стартапах, включая анализ рынка, определение целевой аудитории, позиционирование бренда и использование инструментов цифрового маркетинга. Особое внимание уделяется инновационным подходам, способствующим привлечению клиентов и инвесторов. Результаты исследования показывают, что грамотно разработанная маркетинговая стратегия значительно повышает конкурентоспособность и потенциал развития стартап-проектов.*

Ключевые слова: *стартап, маркетинговый менеджмент, маркетинговая стратегия, цифровой маркетинг, инновационный бизнес, анализ рынка.*

Abstract: *This article examines the formation of marketing management strategies in startup projects and their role in ensuring sustainable business*

development. In the modern digital economy, startups face intense competition and limited resources, which makes effective marketing management crucial for their success. The study analyzes key marketing strategies used by startups, including market research, target audience identification, brand positioning, and the use of digital marketing tools. Particular attention is given to innovative approaches that help startups attract customers and investors. The results of the study show that a well-designed marketing strategy significantly increases the competitiveness and growth potential of startup projects in both local and global markets.

Keywords: *startup, marketing management, marketing strategy, digital marketing, innovative business, market analysis.*

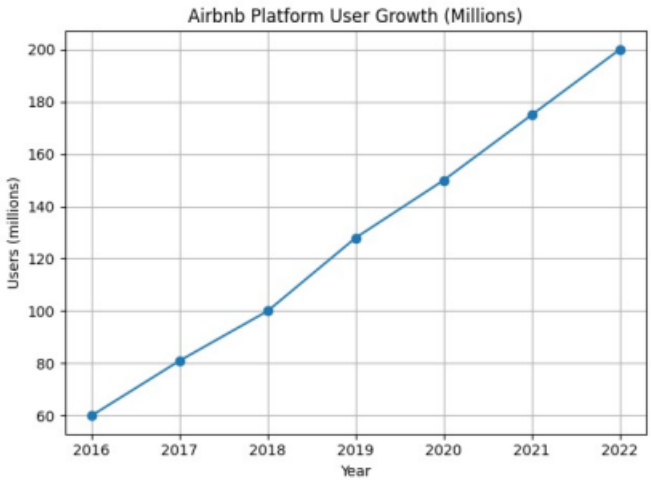
KIRISH

So‘nggi yillarda startaplar ko‘plab mamlakatlarda iqtisodiy o‘sish va innovatsion rivojlanishning muhim omillaridan biriga aylanib bormoqda. Yangi texnologiyalarning rivojlanishi, raqamli iqtisodiyotning shakllanishi hamda bozorlarning globallashuvi startap loyihalarining paydo bo‘lishi va rivojlanishi uchun qulay sharoit yaratmoqda. Startaplar innovatsion mahsulot va xizmatlarni joriy etish, yangi ish o‘rinlarini yaratish hamda bozor raqobatbardoshligini oshirishda muhim rol o‘ynaydi. Biroq startap loyihalarining katta qismi rivojlanishning dastlabki bosqichlarida turli muammolarga duch keladi. Bu muammolarni bartaraf etishda marketing menejmentining samarali tashkil etilishi muhim ahamiyat kasb etadi. Marketing menejmenti bozor imkoniyatlarini tahlil qilish, maqsadli auditoriyani aniqlash, marketing strategiyalarini ishlab chiqish hamda iste’molchilar uchun qiymat yaratishga qaratilgan marketing faoliyatini boshqarish jarayonini o‘z ichiga oladi. Ayniqsa startap loyihalari uchun marketing menejmenti muhim hisoblanadi, chunki startaplar ko‘pincha cheklangan moliyaviy va inson resurslariga ega bo‘ladi hamda bozorda allaqachon shakllangan kompaniyalar bilan raqobatlashishga majbur bo‘ladi. Shu sababli samarali marketing strategiyalarini ishlab chiqish startaplarning barqaror rivojlanishi va muvaffaqiyatga erishishida muhim omil hisoblanadi. Zamonaviy raqamli iqtisodiyot sharoitida marketing vositalari va yondashuvlari ham tez sur’atlarda rivojlanmoqda. Raqamli marketing, ijtimoiy tarmoqlar orqali marketing (SMM), kontent marketing hamda influencer marketing kabi vositalar startaplar uchun mahsulot va xizmatlarni nisbatan kam xarajat bilan targ‘ib qilish imkoniyatini yaratadi. Raqamli texnologiyalar yordamida startaplar keng auditoriyaga chiqish, mijozlar bilan samarali aloqa o‘rnatish hamda bozor talablaridagi o‘zgarishlarga tez moslashish imkoniyatiga ega bo‘ladi. Shuningdek, startap marketing menejmentining muhim jihatlaridan biri bu bozorni chuqur tahlil qilish va maqsadli auditoriyani aniqlashdir. Iste’molchilarning ehtiyojlari, xatti-harakati va talablarini o‘rganish startap loyihalariga bozor talabiga mos innovatsion mahsulotlar yaratish imkonini beradi. Bundan tashqari, brendni to‘g‘ri joylashtirish (positioning) va differensiallash strategiyalarini qo‘llash startaplarga bozorda o‘ziga xos imidj yaratish hamda raqobat ustunligiga erishishga yordam beradi.

TADQIQOT METODOLOGIYASI

Tadqiqotda startap loyihalarida marketing menejment strategiyalarini shakllantirish jarayonini o‘rganish maqsadida bir qator ilmiy tadqiqot usullaridan foydalanildi. Tadqiqot davomida nazariy va amaliy tahlil usullari qo‘llanildi. Birinchidan, ilmiy adabiyotlar tahlili usuli qo‘llanildi. Ushbu usul orqali marketing menejmenti, startap marketingi hamda innovatsion biznesni rivojlantirishga oid ilmiy maqolalar, monografiyalar va xalqaro tadqiqotlar o‘rganildi. Bu esa marketing strategiyalarining nazariy asoslarini aniqlash hamda startap loyihalarida marketing menejmentining o‘ziga xos xususiyatlarini tahlil qilish imkonini berdi. Ikkinchidan, taqqoslash (comparative analysis) usulidan foydalanildi. Ushbu usul yordamida turli startap loyihalarida qo‘llanilayotgan marketing strategiyalari o‘rganildi va ularning samaradorligi baholandi. Taqqoslash jarayonida raqamli marketing, ijtimoiy tarmoqlar orqali marketing hamda brendni rivojlantirish strategiyalarining o‘ziga xos jihatlari tahlil qilindi. Shuningdek, tizimli tahlil usuli qo‘llanilib, startap marketing menejmenti jarayonining asosiy elementlari — bozor tahlili, maqsadli auditoriyani aniqlash, marketing strategiyasini ishlab chiqish hamda marketing faoliyatini amalga oshirish bosqichlari o‘rganildi. Bu usul startap loyihalarida marketing strategiyalarini kompleks tarzda tahlil qilish imkonini berdi. Tadqiqot jarayonida statistik ma’lumotlardan ham foydalanildi. Turli xalqaro tashkilotlar va tadqiqot markazlari tomonidan e’lon qilingan ma’lumotlar asosida startaplarning marketing faoliyati hamda raqamli marketing vositalarining samaradorligi tahlil qilindi.

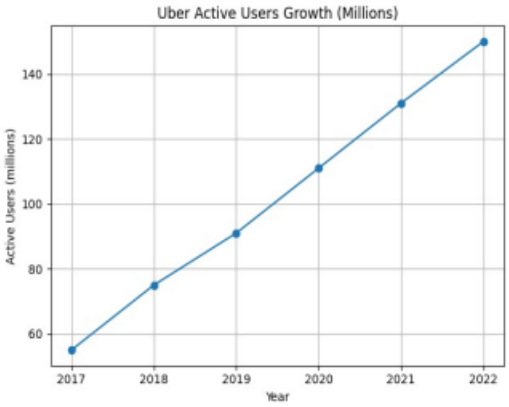
Tadqiqot davomida startap loyihalarida marketing menejment strategiyalarining samaradorligini baholash maqsadida xalqaro miqyosda muvaffaqiyatga erishgan bir nechta startap brendlarining statistik ma’lumotlari tahlil qilindi. Jumladan, **Airbnb, Uber va Spotify** kompaniyalarining foydalanuvchilar soni o‘sishi marketing strategiyalari bilan bog‘liq holda o‘rganildi.



1-diagramma

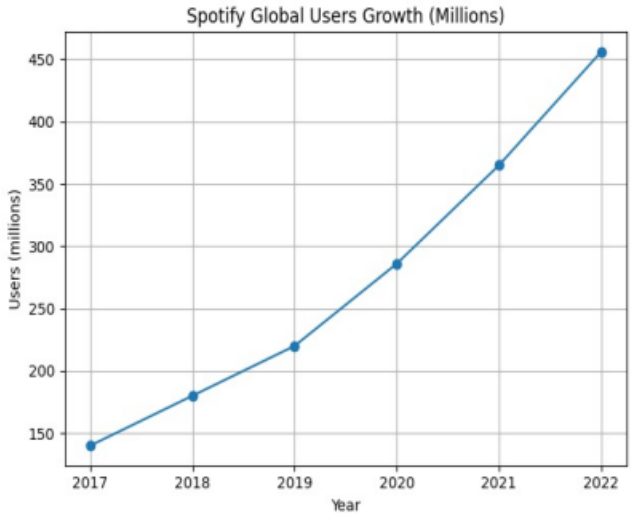
Airbnb platformasining 2016–2022-yillar davomida foydalanuvchilar soni o‘sishi ko‘rsatilgan. Statistik ma’lumotlarga ko‘ra, platforma foydalanuvchilari soni 2016-yilda 60 milliondan 2022-yilda 200 millionga yetgan. Bu o‘sish kompaniyaning raqamli marketing, ijtimoiy tarmoqlar reklamalari hamda kontent marketing strategiyalarini faol qo‘llashi bilan izohlanadi.

2-diagramma



Uber kompaniyasining faol foydalanuvchilari sonining o‘sishi tasvirlangan. 2017-yilda 55 million bo‘lgan foydalanuvchilar soni 2022-yilga kelib 150 milliondan oshgan. Ushbu natija kompaniyaning agressiv marketing strategiyalari, mobil ilova reklamalari hamda mijozlar uchun bonus tizimlari orqali amalga oshirilgan marketing siyosati bilan bog‘liq.

3-diagramma



Spotify platformasining global foydalanuvchilari soni o‘sishi ko‘rsatilgan. 2017-yilda 140 million bo‘lgan foydalanuvchilar soni 2022-yilda 456 millionga yetgan. Bu o‘sishda raqamli marketing, influencer marketing va strategik hamkorlik marketingi muhim rol o‘ynagan. Umuman olganda, tahlil qilingan startaplar tajribasi marketing menejment strategiyalarining startap biznesini tez rivojlantirishda muhim omil ekanligini ko‘rsatadi.

TADQIQOT NATIJALARI

Zamonaviy startaplar marketing menejment strategiyalarini samarali qo‘llash orqali qisqa vaqt ichida katta auditoriyani jalb qilish imkoniyatiga ega bo‘lmoqda. Diagrammalarda ko‘rsatilgan ma’lumotlar startap kompaniyalarining marketing faoliyati va foydalanuvchilar sonining o‘sishi o‘rtasida bevosita bog‘liqlik mavjudligini tasdiqlaydi. Birinchi diagrammada Airbnb platformasining foydalanuvchilar soni barqaror o‘sib borganligi ko‘rinadi. Bu esa kompaniyaning raqamli marketing va platforma iqtisodiyoti modelidan samarali foydalanayotganini ko‘rsatadi. Airbnb marketing strategiyasi asosan ijtimoiy tarmoqlar, foydalanuvchi tajribasi marketingi va onlayn platforma reklamasiga asoslangan. Ikkinchi diagrammada Uber kompaniyasining foydalanuvchilari soni tez sur’atlarda oshgani kuzatiladi. Bu kompaniyaning agressiv marketing siyosati, mijozlarni rag‘batlantirish tizimi va mobil ilova marketing strategiyasining samaradorligini ko‘rsatadi. Uber startap marketingining muvaffaqiyatli modeli sifatida ko‘plab tadqiqotlarda misol sifatida keltiriladi. Uchinchi diagrammada Spotify platformasining foydalanuvchilar soni keskin o‘sib borganligi ko‘rinadi. Bu kompaniya kontent marketing, personalizatsiya algoritmlari va influencer marketing strategiyalaridan samarali foydalangan. Natijada Spotify qisqa vaqt ichida global musiqiy streaming bozorining yetakchi kompaniyalaridan biriga aylandi. Shu sababli zamonaviy startaplar marketing

menejment strategiyalarini ishlab chiqishda raqamli marketing vositalari, mijozlar bilan interaktiv aloqa va innovatsion marketing yondashuvlaridan foydalanishi zarur.

XULOSA

Startap loyihalarida marketing menejment strategiyalarining muhim ahamiyatga ega ekanligini ko‘rsatdi. Airbnb, Uber va Spotify kabi startap kompaniyalarining rivojlanish tajribasi marketing strategiyalarining to‘g‘ri tanlanishi biznes muvaffaqiyatining asosiy omillaridan biri ekanligini tasdiqlaydi. Diagrammalar asosida olib borilgan tahlillar shuni ko‘rsatadiki, raqamli marketing vositalari startap kompaniyalariga qisqa vaqt ichida katta auditoriyani jalb qilish va bozorda mustahkam o‘rin egallash imkonini beradi. Ayniqsa ijtimoiy tarmoqlar marketingi, kontent marketing va mobil ilova marketingi startaplar uchun eng samarali marketing kanallari hisoblanadi. Shuningdek, startap loyihalari marketing strategiyalarini ishlab chiqishda bozor tahliliga, maqsadli auditoriyani aniqlashga va innovatsion marketing yondashuvlariga alohida e’tibor qaratishi zarur. Bu esa startaplarning raqobatbardoshligini oshirish hamda ularning barqaror rivojlanishini ta’minlashga xizmat qiladi. Kelajakda startap marketing menejmenti sohasida raqamli texnologiyalar, sun’iy intellekt va ma’lumotlarga asoslangan marketing strategiyalarining roli yanada ortishi kutilmoqda.

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O‘ZBEKISTON HUDUDIDA AQLLI QISHLOQ XO‘JALIGI TEXNOLOGIYALARINI TATBIQ ETISH HOLATINING TAHLILI

Ergasheva Maftuna Baxrom qizi
Toshkent davlat agrar universiteti tayanch doktoranti

Annotatsiya: *Ushbu maqolada O‘zbekiston hududida aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etish holati tahlil qilingan. Tadqiqotda suv tejovchi sug‘orish tizimlari, lazerli yer tekislash, dronlar, IoT sensorlari, smart issiqxonalar, kosmik monitoring va raqamli agroplatformalarning agrar ishlab chiqarish samaradorligini oshirishdagi o‘rni yoritilgan. Shuningdek, aqlli texnologiyalarni joriy etishning kuchli va zaif tomonlari, mavjud imkoniyatlari hamda ehtimoliy xavf-xatarlari SWOT tahlili asosida baholangan. Maqolada O‘zbekiston sharoitida aqlli qishloq xo‘jaligini rivojlantirish uchun suv resurslaridan oqilona foydalanish, fermerlarning raqamli savodxonligini oshirish, moliyaviy qo‘llab-quvvatlash mexanizmlarini kuchaytirish va yagona raqamli agroplatformani shakllantirish zarurligi asoslab berilgan.*

Kalit so‘zlar: *aqlli qishloq xo‘jaligi, raqamli texnologiyalar, suv tejovchi texnologiyalar, tomchilatib sug‘orish, dronlar, IoT sensorlari, smart issiqxona, kosmik monitoring, raqamli agroplatforma.*

Аннотация: *В данной статье проанализировано состояние внедрения технологий умного сельского хозяйства на территории Узбекистана. В исследовании раскрыта роль водосберегающих систем орошения, лазерной планировки земель, дронов, IoT-сенсоров, умных теплиц, космического мониторинга и цифровых агроплатформ в повышении эффективности аграрного производства. Также на основе SWOT-анализа оценены сильные и слабые стороны, возможности и потенциальные угрозы внедрения умных технологий. В статье обоснована необходимость рационального использования водных ресурсов, повышения цифровой грамотности фермеров, усиления механизмов финансовой поддержки и формирования единой цифровой агроплатформы для развития умного сельского хозяйства в условиях Узбекистана.*

Ключевые слова: *умное сельское хозяйство, цифровые технологии, водосберегающие технологии, капельное орошение, дроны, IoT-сенсоры, умная теплица, космический мониторинг, цифровая агроплатформа.*

Abstract: *This article analyzes the current state of implementing smart agriculture technologies in Uzbekistan. The study examines the role of water-saving irrigation systems, laser land leveling, drones, IoT sensors, smart greenhouses, satellite monitoring, and digital agro-platforms in improving the efficiency of agricultural production. The strengths, weaknesses, opportunities, and potential threats of smart technology implementation are also assessed through SWOT analysis. The article substantiates the need for rational use of water resources, improvement of farmers’ digital literacy, strengthening of financial support mechanisms, and*

development of a unified digital agro-platform for advancing smart agriculture in Uzbekistan.

Keywords: *smart agriculture, digital technologies, water-saving technologies, drip irrigation, drones, IoT sensors, smart greenhouse, satellite monitoring, digital agro-platform.*

KIRISH

Bugungi globallashuv, raqamli transformatsiya va iqlim o‘zgarishlari sharoitida qishloq xo‘jaligi tarmog‘ini innovatsion asosda rivojlantirish, ishlab chiqarish jarayonlariga zamonaviy raqamli texnologiyalarni joriy etish hamda mavjud resurslardan samarali foydalanish masalalari tobora dolzarb ahamiyat kasb etmoqda. Jahon amaliyotida “aqlli qishloq xo‘jaligi” texnologiyalari qishloq xo‘jaligi ishlab chiqarishida samaradorlikni oshirish, suv, yer, energiya va mehnat resurslaridan oqilona foydalanish, mahsulot yetishtirish jarayonlarini real vaqt rejimida kuzatish hamda ekologik barqarorlikni ta’minlashning muhim vositasi sifatida namoyon bo‘lmoqda.

Aqlli qishloq xo‘jaligi texnologiyalari deganda sun’iy intellekt, masofadan zondlash, dronlar, GPS/GIS texnologiyalari, IoT qurilmalari, aqlli sug‘orish tizimlari, sensorlar, raqamli monitoring platformalari va katta ma’lumotlar tahliliga asoslangan boshqaruv yechimlari tushuniladi. Ushbu texnologiyalar fermer xo‘jaliklari, klasterlar va agrofirmalarga ekin maydonlari holatini kuzatish, tuproq namligini aniqlash, suv sarfini optimallashtirish, kasallik va zararkunandalarni erta aniqlash, hosildorlikni prognozlash hamda ishlab chiqarish xarajatlarini kamaytirish imkonini beradi. Shu jihatdan aqlli qishloq xo‘jaligi texnologiyalari an’anaviy agrar boshqaruvdan raqamli, aniq ma’lumotlarga asoslangan va samaradorlikka yo‘naltirilgan boshqaruv tizimiga o‘tishning muhim omili hisoblanadi.

O‘zbekiston iqtisodiyotida qishloq xo‘jaligi strategik ahamiyatga ega tarmoqlardan biri bo‘lib, oziq-ovqat xavfsizligini ta’minlash, aholi bandligini oshirish, eksport salohiyatini kengaytirish va hududiy rivojlanishni jadallashtirishda muhim o‘rin tutadi. Rasmiy statistik ma’lumotlarga ko‘ra, 2025-yil yanvar–dekabr oylarida O‘zbekiston Respublikasida qishloq, o‘rmon va baliq xo‘jaligi mahsulotlari hamda xizmatlari hajmi 538 919,7 mlrd so‘mni tashkil etib, 2024-yilning mos davriga nisbatan 104,4 foizga o‘sgan [1]. Mazkur ko‘rsatkich qishloq xo‘jaligi tarmog‘ining iqtisodiyotdagi salmog‘i yuqoriligini, shuningdek, ushbu sohada ishlab chiqarish samaradorligini oshirishga qaratilgan zamonaviy texnologik yechimlarga ehtiyoj ortib borayotganini ko‘rsatadi.

O‘zbekiston hududida aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etish zarurati bir necha omillar bilan izohlanadi. Avvalo, mamlakatda suv resurslaridan samarali foydalanish masalasi dolzarb bo‘lib, ayniqsa sug‘oriladigan yer maydonlarida suv tejovchi va aqlli sug‘orish texnologiyalarini keng joriy etish muhim ahamiyatga ega. Ikkinchidan, iqlim o‘zgarishi, tuproq unumdorligining pasayishi, ayrim hududlarda sho‘rlanish va degradatsiya jarayonlari qishloq xo‘jaligida aniq monitoring, tezkor tahlil va ilmiy asoslangan qarorlar qabul qilish zaruratini kuchaytirmoqda. Uchinchidan, qishloq xo‘jaligi mahsulotlari yetishtirishda raqobatbardoshlikni oshirish,

eksportbop mahsulotlar hajmini ko‘paytirish va xalqaro sifat talablariga mos ishlab chiqarishni yo‘lga qo‘yish raqamli texnologiyalarni keng qo‘llashni talab etadi.

Shu bilan birga, aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etish holatini tahlil qilish nafaqat texnologik yangilanish darajasini baholash, balki mavjud muammolar, hududiy tafovutlar, infratuzilmaviy cheklovlar, fermer xo‘jaliklarining raqamli savodxonligi, moliyaviy imkoniyatlar va institutsional qo‘llab-quvvatlash mexanizmlarini aniqlash imkonini beradi. Chunki aqlli texnologiyalarni joriy etish jarayoni faqat texnik vositalarni xarid qilish bilan cheklanmaydi, balki ularni samarali boshqarish, ma’lumotlarni qayta ishlash, malakali kadrlar tayyorlash, raqamli infratuzilmani rivojlantirish va innovatsion ekotizimni shakllantirish bilan bevosita bog‘liqdir.

ADABIYOTLAR TAHLILI

So‘nggi yillarda aqlli qishloq xo‘jaligi texnologiyalari agrar sohani modernizatsiya qilish, resurslardan samarali foydalanish, hosildorlikni oshirish va iqlim o‘zgarishlari ta’sirini yumshatishda muhim vosita sifatida qaralmoqda. Ushbu texnologiyalarning ilmiy tadqiqotlar va amaliyotda keng qo‘llanilishi xalqaro ilmiy jamoatchilik tomonidan atroflicha o‘rganilgan. Aqlli qishloq xo‘jaligi texnologiyalari tarkibida sun’iy intellekt, buyumlar interneti, katta ma’lumotlar, masofadan zondlash, GPS/GIS tizimlari, dronlar, aqlli sensorlar va avtomatlashtirilgan sug‘orish tizimlari alohida o‘rin egallaydi. Mazkur tadqiqotlar aqlli qishloq xo‘jaligi texnologiyalarining ishlab chiqarish samaradorligini oshirish, suv va yer resurslaridan oqilona foydalanish, ekinlar holatini real vaqt rejimida monitoring qilish hamda fermer xo‘jaliklarida ma’lumotlarga asoslangan qarorlar qabul qilishdagi ahamiyatini ko‘rsatib beradi.

Tadqiqotchi S.Wolfert va uning hammualliflari tomonidan amalga oshirilgan “Big Data in Smart Farming – A review” nomli tadqiqotda aqlli qishloq xo‘jaligida katta ma’lumotlardan foydalanish imkoniyatlari keng tahlil qilingan. Mualliflar katta ma’lumotlar faqat ishlab chiqarish jarayonlarini boshqarish bilangina cheklanmasdan, balki butun oziq-ovqat ta’minot zanjiriga ta’sir ko‘rsatishini asoslab berganlar. Tadqiqot natijalariga ko‘ra, katta ma’lumotlar texnologiyalari fermer xo‘jaliklari, agrar korxonalar va ta’minot zanjiri ishtirokchilari o‘rtasida axborot almashinuvini yaxshilaydi, qaror qabul qilish jarayonini tezlashtiradi va ishlab chiqarish samaradorligini oshirishga xizmat qiladi [2].

A.Tzounis, N.Katsoulas, T.Bartzanas va C.Kittas tomonidan olib borilgan “Internet of Things in agriculture, recent advances and future challenges” nomli tadqiqotda qishloq xo‘jaligida buyumlar interneti texnologiyalarining qo‘llanish imkoniyatlari yoritilgan. Mualliflar IoT texnologiyalari yordamida issiqxonalar, ekin maydonlari, sug‘orish tizimlari va tuproq holatini masofadan nazorat qilish imkoniyati kengayishini ta’kidlaydilar. Tadqiqotda aqlli sensorlar, simsiz tarmoqlar va avtomatlashtirilgan nazorat tizimlari fermerlarga real vaqt rejimida ma’lumot olish, suv sarfini kamaytirish va ekinlar parvarishini aniq boshqarish imkonini berishi ko‘rsatib o‘tilgan [3].

K.G.Liakos va hammualliflari tomonidan e’lon qilingan “Machine Learning in Agriculture: A Review” nomli maqolada mashinaviy o‘rganish texnologiyalarining

qishloq xo‘jaligi ishlab chiqarish tizimlaridagi o‘rni tahlil qilingan. Tadqiqotchilar mashinaviy o‘rganish usullari hosildorlikni prognozlash, kasallik va zararkunandalarni aniqlash, tuproq xususiyatlarini baholash, sug‘orish jarayonlarini optimallashtirish hamda mahsulot sifatini nazorat qilishda samarali qo‘llanishini asoslab berganlar. Ularning fikricha, mashinaviy o‘rganish algoritmlari agrar sohada an’anaviy tajribaga asoslangan boshqaruvdan ma’lumotlarga tayangan aniq qarorlar qabul qilish tizimiga o‘tish imkonini beradi [4].

A.Kamilaris va F.X.Prenafeta-Boldú tomonidan olib borilgan “Deep Learning in Agriculture: A Survey” nomli tadqiqotda chuqur o‘rganish texnologiyalarining qishloq xo‘jaligidagi amaliy qo‘llanilishi keng yoritilgan. Mualliflar 40 ta ilmiy tadqiqotni tahlil qilgan holda, chuqur o‘rganish texnologiyalari asosan o‘simlik kasalliklarini aniqlash, begona o‘tlarni tasniflash, hosildorlikni baholash, meva va sabzavotlar sifatini aniqlash hamda masofadan olingan tasvirlarni qayta ishlashda yuqori natija berishini ko‘rsatganlar. Ushbu tadqiqot aqlli qishloq xo‘jaligida sun’iy intellektning, ayniqsa tasvirlarni tahlil qilish va avtomatik diagnostika jarayonlaridagi imkoniyatlarini ochib beradi [5].

A.Soussi, E.Zero, R.Sacile, D.Trinchero va M.Fossa tomonidan tayyorlangan “Smart Sensors and Smart Data for Precision Agriculture: A Review” nomli tadqiqotda aqlli sensorlar va aqlli ma’lumotlarning aniq qishloq xo‘jaligidagi o‘rni tahlil qilingan. Tadqiqotda sensorlar, IoT, katta ma’lumotlar tahlili va sun’iy intellekt texnologiyalarining integratsiyasi ekinlarni boshqarish, suv, o‘g‘it va pestitsidlardan oqilona foydalanish, hosildorlikni oshirish va ekologik ta’sirni kamaytirishda muhim ahamiyat kasb etishi ko‘rsatib berilgan. Mualliflar aqlli sensorlar zamonaviy qishloq xo‘jaligida ma’lumotlar oqimini shakllantirish va fermer qarorlarini ilmiy asoslashning muhim vositasiga aylanayotganini ta’kidlaydilar [6].

FAO tomonidan ilgari surilgan “Digital Agriculture and AI Innovation” yondashuvlarida raqamli qishloq xo‘jaligi va sun’iy intellekt agrar-oziq-ovqat tizimlarini transformatsiya qilishning muhim yo‘nalishi sifatida talqin etiladi. FAO ma’lumotlariga ko‘ra, raqamli texnologiyalar va sun’iy intellekt aniq dehqonchilik, iqlimga mos qishloq xo‘jaligi, ta’minot zanjirlarini optimallashtirish va bozorga kirish imkoniyatlarini kengaytirish orqali agrar tizimlarni samaraliroq, barqarorroq va chidamliroq qilishga xizmat qiladi. Bu yondashuv O‘zbekiston sharoitida ham raqamli agrotexnologiyalarni fermer xo‘jaliklari, klasterlar va hududiy agrar boshqaruv tizimlariga joriy etish zarurligini ko‘rsatadi [7].

O‘zbekiston sharoitida aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etishda suv resurslaridan samarali foydalanish masalasi alohida ahamiyatga ega. Jahon bankining 2025-yil 21-maydagi ma’lumotiga ko‘ra, O‘zbekistonda irrigatsiya va drenaj infratuzilmasini modernizatsiya qilish hamda sug‘orish xizmatlari sifatini yaxshilash uchun 200 mln AQSH dollari miqdorida imtiyozli kredit ajratilgan. Mazkur loyiha doirasida suv yo‘qotishlarini kamaytirish, irrigatsiya tizimlarining energiya samaradorligini oshirish va qishloq xo‘jaligida suvdan foydalanish samaradorligini kuchaytirish nazarda tutilgan. Ushbu holat aqlli sug‘orish, sensorli monitoring, SCADA tizimlari va suv sarfini raqamli nazorat qilish texnologiyalarining O‘zbekiston agrar sektori uchun dolzarbligini tasdiqlaydi [8].

FAOning O‘zbekistondagi Digital Villages Initiative dasturi doirasida ham qishloq joylarda raqamli texnologiyalarni joriy etish bo‘yicha muhim tashabbuslar amalga oshirilmoqda. Xususan, Farg‘ona vodiysidagi Novkent va Yuksalish qishloqlari smart issiqxona texnologiyalari, raqamli ko‘nikmalar va bozorga chiqish imkoniyatlarini kengaytirish bo‘yicha pilot hududlar sifatida ko‘rsatilgan. FAO ma’lumotlarida O‘zbekiston qishloq xo‘jaligida suv tanqisligi, qishloq xo‘jaligi texnikalarining yetishmasligi va shahar-qishloq o‘rtasidagi raqamli tafovutni qisqartirish kabi muammolar mavjudligi qayd etiladi. Bu esa aqlli qishloq xo‘jaligi texnologiyalarini joriy etish faqat texnologik jarayon emas, balki institutsional, infratuzilmaviy va ijtimoiy yondashuvlarni ham talab etishini ko‘rsatadi [9].

Yuqoridagi tadqiqotlar shuni ko‘rsatadiki, aqlli qishloq xo‘jaligi texnologiyalari zamonaviy agrar rivojlanishning muhim yo‘nalishlaridan biri hisoblanadi. Xalqaro ilmiy adabiyotlarda IoT, sun’iy intellekt, katta ma’lumotlar, aqlli sensorlar va masofadan zondlash texnologiyalarining qishloq xo‘jaligi samaradorligini oshirishdagi o‘rni keng asoslangan. O‘zbekiston sharoitida esa mazkur texnologiyalarni tatbiq etish suv resurslaridan oqilona foydalanish, hosildorlikni oshirish, hududlar kesimida agrar salohiyatni rivojlantirish, fermer xo‘jaliklarida raqamli boshqaruvni yo‘lga qo‘yish va qishloq joylarda innovatsion infratuzilmani shakllantirish nuqtayi nazaridan alohida dolzarb ahamiyatga ega.

METODOLOGIYA

O‘zbekiston hududida aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etish holatini tahlil qilishda tizimli tahlil, statistik tahlil, qiyosiy tahlil, SWOT tahlil hamda indikatorli baholash metodlaridan foydalanish maqsadga muvofiq hisoblanadi. Ushbu metodlar aqlli qishloq xo‘jaligi texnologiyalarining mavjud joriy etilish darajasi, hududiy xususiyatlari, resurslardan foydalanish samaradorligi, institutsional shart-sharoitlari va rivojlanish istiqbollarini kompleks baholash imkonini beradi.

Tizimli tahlil metodi aqlli qishloq xo‘jaligi texnologiyalarini alohida texnik vositalar majmui sifatida emas, balki qishloq xo‘jaligi ishlab chiqarishi, raqamli infratuzilma, suv resurslari, fermer xo‘jaliklari, agroklasterlar, investitsion imkoniyatlar, kadrlar salohiyati va davlat qo‘llab-quvvatlashi bilan bog‘liq yaxlit tizim sifatida o‘rganishga xizmat qiladi. Ushbu metod yordamida aqlli sug‘orish tizimlari, sensorlar, dronlar, GPS/GIS texnologiyalari, masofadan monitoring qilish platformalari va ma’lumotlarga asoslangan boshqaruv mexanizmlarining agrar ishlab chiqarish jarayonidagi o‘rni aniqlanadi.

Statistik tahlil metodi O‘zbekiston qishloq xo‘jaligida aqlli texnologiyalarni joriy etish zaruratini miqdoriy ko‘rsatkichlar asosida asoslash imkonini beradi. Ushbu metod orqali qishloq xo‘jaligi mahsulotlari hajmi, ekin maydonlari, hosildorlik darajasi, suv tejovchi texnologiyalar joriy etilgan maydonlar, qishloq xo‘jaligiga yo‘naltirilgan investitsiyalar, texnik va raqamli infratuzilma bilan ta’minlanganlik kabi ko‘rsatkichlar tahlil qilinadi. Statistik tahlil natijalari aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etish holatini real raqamlar asosida baholashga xizmat qiladi.

Qiyosiy tahlil metodi aqlli qishloq xo‘jaligi texnologiyalarining an’anaviy agrar boshqaruv usullaridan farqli jihatlarini aniqlashda qo‘llaniladi. Ushbu metod

yordamida an’anaviy dehqonchilik va raqamli texnologiyalarga asoslangan dehqonchilik yondashuvlari suv sarfi, mehnat unumdorligi, hosildorlik, ishlab chiqarish xarajatlari, agrotexnik tadbirlarni bajarish aniqligi va qaror qabul qilish tezligi kabi mezonlar bo‘yicha taqqoslanadi. Shuningdek, hududlar kesimida aqlli texnologiyalarni joriy etish darajasidagi tafovutlarni aniqlashda ham qiyosiy tahlil muhim ahamiyatga ega.

SWOT tahlil metodi O‘zbekiston sharoitida aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etishning kuchli tomonlari, zaif jihatlari, mavjud imkoniyatlari va ehtimoliy xavf-xatarlarini aniqlash uchun qo‘llaniladi. Ushbu metod yordamida suv tejovchi texnologiyalarni kengaytirish, davlat tomonidan agrar sohani modernizatsiya qilishga qaratilgan islohotlar, agroklasterlar faoliyati va raqamli texnologiyalar bozorining rivojlanishi kuchli jihatlar hamda imkoniyatlar sifatida baholanadi. Shu bilan birga, texnologiyalarning yuqori qiymati, fermer xo‘jaliklarining moliyaviy imkoniyatlari cheklanganligi, raqamli savodxonlik darajasidagi tafovutlar va ayrim hududlarda internet infratuzilmasining yetarli emasligi zaif jihatlar hamda xavf omillari sifatida tahlil qilinadi.

Indikatorli baholash metodi aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etish darajasini kompleks baholash imkonini beradi. Ushbu metod asosida raqamli infratuzilma, suv tejovchi texnologiyalar ulushi, fermer xo‘jaliklarining innovatsion faolligi, investitsion imkoniyatlar, texnik ta’minot, kadrlar salohiyati va davlat qo‘llab-quvvatlashi kabi indikatorlar tanlab olinadi. Mazkur indikatorlar asosida hududlar yoki xo‘jalik subyektlarining aqlli qishloq xo‘jaligi texnologiyalarini joriy etishga tayyorgarlik darajasi baholanadi.

Yuqoridagi metodlardan foydalanish O‘zbekiston hududida aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etish holatini kompleks tahlil qilish, mavjud muammolarni aniqlash, hududiy tafovutlarni baholash hamda texnologiyalarni keng joriy etish bo‘yicha ilmiy asoslangan takliflar ishlab chiqish imkonini beradi. Mazkur metodologik yondashuv aqlli qishloq xo‘jaligi texnologiyalarining nafaqat texnologik, balki iqtisodiy, institutsional, infratuzilmaviy va hududiy jihatlarini ham qamrab olishi bilan ahamiyatlidir.

MUHOKAMA VA NATIJALAR

So‘nggi yillarda jahon qishloq xo‘jaligida raqamli transformatsiya jarayonlari keskin jadallashib, aqlli qishloq xo‘jaligi texnologiyalari agrar ishlab chiqarish samaradorligini oshirishning muhim omiliga aylanmoqda. Xususan, sun’iy intellekt, buyumlar interneti, masofadan zondlash, dronlar, GPS/GIS tizimlari, aqlli sensorlar, avtomatlashtirilgan sug‘orish tizimlari va katta ma’lumotlar tahlili asosida fermer xo‘jaliklarida qaror qabul qilish jarayonlari raqamlashtirilmoqda. Bunday texnologiyalar ishlab chiqarish xarajatlarini kamaytirish, suv va o‘g‘it sarfini optimallashtirish, hosildorlikni prognozlash, ekinlar kasalliklarini erta aniqlash hamda agrar ishlab chiqarishning ekologik barqarorligini oshirishga xizmat qilmoqda.

Jahon bozorida aqlli qishloq xo‘jaligi texnologiyalariga talabning ortib borayotgani ushbu yo‘nalishning iqtisodiy ahamiyatini ham tasdiqlaydi. Xalqaro bozor tahlillariga ko‘ra, global aqlli qishloq xo‘jaligi bozori 2024-yilda 25,36 mlrd AQSH

dollarini tashkil etgan bo‘lsa, 2025-yilda 28,51 mlrd AQSH dollariga yetishi kutilmoqda. 2025–2033-yillar davomida mazkur bozorning o‘rtacha yillik o‘sish sur’ati 14,6 foiz bo‘lishi va 2033-yilga kelib 83,72 mlrd AQSH dollariga yetishi prognoz qilinmoqda [10]. Bu holat dunyo miqyosida an’anaviy agrar ishlab chiqarishdan raqamli va ma’lumotlarga asoslangan qishloq xo‘jaligi boshqaruviga o‘tish jarayoni kuchayayotganini ko‘rsatadi.

Aqlli qishloq xo‘jaligi texnologiyalarining jadal rivojlanishiga bir necha omillar ta’sir ko‘rsatmoqda. Birinchidan, global oziq-ovqat xavfsizligini ta’minlash zarurati ishlab chiqarish samaradorligini oshirishni talab qilmoqda. Ikkinchidan, suv tanqisligi, iqlim o‘zgarishi, tuproq degradatsiyasi va ekin maydonlarining cheklanganligi resurslardan oqilona foydalanishni dolzarb masalaga aylantirmoqda. Uchinchidan, zamonaviy iste’mol bozorlari mahsulot sifati, xavfsizligi va kuzatuvchanligi bo‘yicha yuqori talablarni ilgari surmoqda. Shu bois rivojlangan mamlakatlarda aqlli sug‘orish, smart greenhouse, aniq dehqonchilik, avtomatlashtirilgan monitoring va raqamli ta’minot zanjirlari qishloq xo‘jaligining asosiy rivojlanish yo‘nalishlaridan biriga aylanmoqda.

O‘zbekiston sharoitida ham aqlli qishloq xo‘jaligi texnologiyalarini joriy etish zarurati agrar sohaning iqtisodiyotdagi o‘rni, suv resurslariga yuqori bog‘liqlik, hududiy iqlim farqlari va qishloq xo‘jaligi ishlab chiqarishini modernizatsiya qilish ehtiyoji bilan bevosita bog‘liq. Rasmiy statistik ma’lumotlarga ko‘ra, 2025-yil yanvar–dekabr oylarida O‘zbekiston Respublikasida qishloq, o‘rmon va baliq xo‘jaligi mahsulotlari hamda xizmatlari hajmi 538 919,7 mlrd so‘mni tashkil etib, 2024-yilning mos davriga nisbatan 104,4 foizga o‘sgan [11]. Ushbu ko‘rsatkich qishloq xo‘jaligi tarmog‘ining iqtisodiyotdagi muhim o‘rnini hamda uning samaradorligini oshirish uchun innovatsion va raqamli texnologiyalarni keng joriy etish zarurligini ko‘rsatadi.

O‘zbekistonda aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etishda eng muhim yo‘nalishlardan biri suv resurslaridan samarali foydalanish hisoblanadi. Jahon banki ma’lumotlariga ko‘ra, O‘zbekistonda qishloq xo‘jaligi mamlakat YaIMi va bandligining qariyb 25 foizini shakllantiradi, shu bilan birga, mamlakat suv iste’molining taxminan 90 foizi agrar sohaga to‘g‘ri keladi [12]. Bu holat aqlli sug‘orish tizimlari, tuproq namligini aniqlovchi sensorlar, suv sarfini real vaqt rejimida kuzatuvchi raqamli platformalar va irrigatsiya tizimlarini avtomatlashtirish texnologiyalarini joriy etishning amaliy zaruratini kuchaytiradi.

Suv resurslari bilan bog‘liq xavflar O‘zbekiston uchun uzoq muddatli strategik masala hisoblanadi. Jahon banki baholashlariga ko‘ra, iqlim o‘zgarishi ta’sirida O‘zbekistonda suv mavjudligi 30–40 foizga kamayishi, sug‘orishga bo‘lgan talab esa 25 foizga ortishi mumkin [13]. Bundan tashqari, mamlakatda qariyb 2,4 mln gektar qishloq xo‘jaligi yeri, ya’ni sug‘oriladigan maydonlarning 56 foizi nasoslar orqali suv bilan ta’minlanadi. Irrigatsiyada foydalaniladigan 1700 ta nasos stansiyasi yiliga 7,2 mlrd kVt·soat elektr energiyasini iste’mol qiladi, bu esa mamlakat elektr energiyasi iste’molining qariyb 16 foiziga teng. Ushbu raqamlar aqlli suv boshqaruvi, energiya tejamkor nasos stansiyalari, raqamli monitoring va avtomatlashtirilgan irrigatsiya tizimlarini joriy etish agrar soha samaradorligini oshirishning muhim sharti ekanini ko‘rsatadi.

O‘zbekistonda suv tejovchi texnologiyalarni kengaytirish bo‘yicha maqsadli chora-tadbirlar amalga oshirilmoqda. 2030-yilga qadar mamlakatda 2 mln gektar maydonda suv tejovchi sug‘orish tizimlarini joriy etish, irrigatsiya kanallarini modernizatsiya qilish va nasos stansiyalarini energiya tejamkor texnologiyalar bilan almashtirish rejalashtirilgan [14]. Bu yo‘nalish aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etish uchun muhim infratuzilmaviy asos yaratadi. Ayniqsa, tomchilatib sug‘orish, yomg‘irlatib sug‘orish, diskret sug‘orish, lazerli yer tekislash va suv sarfini raqamli nazorat qilish texnologiyalari O‘zbekistonning sug‘oriladigan dehqonchilik tizimi uchun muhim ahamiyatga ega.

O‘zbekiston hududlarida aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etish bo‘yicha ayrim amaliy tashabbuslar ham shakllanmoqda. FAOning Digital Villages Initiative dasturi doirasida Farg‘ona vodiysida raqamli qishloqlar, smart issiqxonalar va fermerlarning raqamli ko‘nikmalarini rivojlantirishga qaratilgan loyihalar amalga oshirilmoqda. FAO ma’lumotlariga ko‘ra, O‘zbekistonda Digital Villages Initiative qishloq joylarida raqamli tafovutni qisqartirish, fermerlarni raqamli va agro-tadbirkorlik ko‘nikmalari bilan ta’minlash hamda qishloq xo‘jaligida innovatsion yechimlarni qo‘llab-quvvatlashga qaratilgan. Bu holat aqlli qishloq xo‘jaligi texnologiyalarini faqat yirik agroklasterlarda emas, balki kichik fermer va dehqon xo‘jaliklari darajasida ham bosqichma-bosqich joriy etish imkoniyati mavjudligini ko‘rsatadi.

Tahlillar shuni ko‘rsatadiki, O‘zbekiston hududida aqlli qishloq xo‘jaligi texnologiyalarini joriy etish holati hali to‘liq tizimli tus olmagan bo‘lsa-da, ushbu yo‘nalishda muhim institutsional va texnologik asoslar shakllanmoqda. Bir tomondan, davlat tomonidan suv tejovchi texnologiyalar, irrigatsiya tizimlarini modernizatsiya qilish, raqamli platformalar va agroinnovatsiyalarni qo‘llab-quvvatlash bo‘yicha dasturlar amalga oshirilmoqda. Ikkinchi tomondan, fermer xo‘jaliklari va agroklasterlarda raqamli monitoring, aqlli sug‘orish, issiqxona avtomatik boshqaruvi, dronlardan foydalanish va masofadan kuzatuv kabi texnologiyalarni keng joriy etish uchun moliyaviy, texnik va kadrlar bilan bog‘liq cheklovlar saqlanib qolmoqda.

Aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etish jarayonida asosiy muammolardan biri hududlar o‘rtasidagi raqamli infratuzilma va texnologik tayyorgarlik darajasidagi tafovutlar hisoblanadi. Internet sifati, sensor va monitoring uskunalarining narxi, fermerlarning raqamli savodxonligi, servis xizmatlari mavjudligi, texnologiyalarni moliyalashtirish mexanizmlari hamda ma’lumotlarni tahlil qilish bo‘yicha mutaxassislar yetishmasligi aqlli texnologiyalarni ommalashtirishga ta’sir ko‘rsatmoqda. Shu sababli aqlli qishloq xo‘jaligini rivojlantirishda faqat texnik vositalarni xarid qilish emas, balki raqamli ekotizim, servis infratuzilmasi, o‘quv markazlari, subsidiyalar, imtiyozli kreditlar va amaliy konsalting xizmatlarini birgalikda rivojlantirish zarur.

O‘zbekiston qishloq xo‘jaligida aqlli texnologiyalarni tatbiq etish jarayoni so‘nggi yillarda alohida yo‘nalish sifatida shakllanmoqda. Ushbu jarayon, bir tomondan, suv tanqisligi, iqlim o‘zgarishi, tuproq unumdorligini saqlash va hosildorlikni oshirish kabi dolzarb muammolar bilan bog‘liq bo‘lsa, ikkinchi tomondan, agrar boshqaruvni raqamlashtirish, ekin maydonlari holatini masofadan monitoring

qilish, fermerlar uchun raqamli xizmatlar yaratish va resurslardan tejamkor foydalanish ehtiyoji bilan izohlanadi. O‘zbekiston tajribasida aqlli qishloq xo‘jaligi texnologiyalari asosan suv tejovchi sug‘orish tizimlari, IoT sensorlari, smart issiqxonalar, dronlar, sun’iy intellekt, kosmik monitoring, raqamli xaritalar, avtomatlashtirilgan texnikalar va integratsion platformalar ko‘rinishida namoyon bo‘lmoqda.

O‘zbekistonda aqlli qishloq xo‘jaligi texnologiyalarining qo‘llanish yo‘nalishlari va qamrov ko‘rsatkichlari[15]

№	QISHLOQ XO‘JALIGIDAGI QO‘LLANISH YO‘NALISHI	TATBIQ ETILAYOTGAN AQLLI TEXNOLOGIYA	2025-YIL YOKI MAVJUD OCHIQ MA’LUMOT BO‘YICHA QAMROV	ULUSHI / FOIZI
1	Suv resurslarini tejash va aniq sug‘orish	Tomchilatib sug‘orish texnologiyasi	2025-yilda 103,2 ming gektarda joriy qilingan	2025-yilda joriy qilingan jami suv tejovchi texnologiyalar maydonining **12,6 %**
2	Suv resurslarini tejash va maydonlarni bir tekis sug‘orish	Yomg‘irlatib sug‘orish texnologiyasi	2025-yilda 30,7 ming gektarda joriy qilingan	**3,8 %**
3	Sug‘orish jarayonlarini tartibli boshqarish	Diskret sug‘orish texnologiyasi	2025-yilda 13,7 ming gektarda joriy qilingan	**1,7 %**
4	Egatlar bo‘yicha suv yetkazishni optimallashtirish	Egiluvchan quvurlar orqali sug‘orish	2025-yilda 74 ming gektarda joriy qilingan	**9,1 %**
5	An’anaviy sug‘orishni takomillashtirish	Egatga plyonka to‘shab sug‘orish	2025-yilda 49 ming gektarda joriy qilingan	**6,0 %**
6	Yer resurslarini tayyorlash va suvdan foydalanish samaradorligi	Lazerli yer tekislash	2025-yilda 546 ming gektarda amalga oshirilgan	**66,8 %**
7	Ekin maydonlarini masofadan monitoring qilish	Dronlar va UAV texnologiyalari	Qishloq xo‘jaligida 100 dan ortiq dron ekin monitoringi va agrotexnik tadbirlar uchun ishlatilmoqda	Umumiy maydon kesimida rasmiy foiz berilmagan
8	O‘g‘itlash va zararkunandalarga qarshi ishlov berish	Agrodronlar	Dronlardan o‘g‘itlash, monitoring va turli agrotexnik vazifalarda foydalanish amaliyoti kengaymoqda	Umumiy qamrov bo‘yicha rasmiy foiz ochiq manbada ko‘rsatilmagan
9	Issiqxona xo‘jaligini raqamli boshqarish	IoT sensorlari va smart greenhouse texnologiyalari	Farg‘ona vodiysida FAO Digital Villages Initiative doirasida smart issiqxonalar va IoT sensorlari pilot tarzda joriy etilmoqda	Pilot loyiha; respublika bo‘yicha foizli qamrov berilmagan
10	Yer va suv resurslarini masofadan kuzatish	Kosmik monitoring va aerokosmik ma’lumotlar	4 mln gektardan ortiq yer kosmik monitoring qilingan, 60 ta yirik suv ombori batimetrik tahlildan o‘tkazilgan	Monitoring qilingan yer maydoni katta qamrovga ega, lekin umumiy agrar maydonga nisbatan rasmiy foiz berilmagan
11	Raqamli agrar boshqaruv	“Raqamli qishloq xo‘jaligi” yagona integratsion platformasi	Fermerlar foydalanayotgan 30 dan ortiq platformani integratsiya qilish belgilangan	Platformalar soni bo‘yicha integratsiya yo‘nalishi; foizli qamrov berilmagan

№	QISHLOQ XO‘JALIGIDAGI QO‘LLANISH YO‘NALISHI	TATBIQ ETILAYOTGAN AQLLI TEXNOLOGIYA	2025-YIL YOKI MAVJUD OCHIQ MA’LUMOT BO‘YICHA QAMROV	ULUSHI / FOIZI
12	Dala ishlarini avtomatlashtirish	Haydovchisiz boshqariladigan aqlli texnika va AGV	Toshkent viloyati Yangiyo‘l tumanida haydovchisiz boshqaruv texnikasi dala sharoitida sinovdan o‘tkazilgan	Pilot loyiha; ommaviy foizli qamrov mavjud emas

Jadval ma’lumotlari shuni ko‘rsatadiki, O‘zbekistonda aqlli qishloq xo‘jaligi texnologiyalari ichida eng yuqori amaliy qamrov suv tejovchi texnologiyalar bilan bog‘liq. 2025-yilda jami 817,2 ming gektar maydonda suv tejovchi texnologiyalar joriy qilingan bo‘lib, ushbu tarkibda eng katta ulush lazerli yer tekislashga to‘g‘ri keladi — 546 ming gektar yoki 66,8 foiz. Bu holat O‘zbekiston qishloq xo‘jaligida aqlli texnologiyalarning dastlabki keng ko‘lamli tatbiqi avvalo suvdan foydalanish samaradorligini oshirish, sug‘orish jarayonini optimallashtirish va yer maydonlarini texnologik jihatdan tayyorlash bilan bog‘liq ekanligini ko‘rsatadi.

Tomchilatib sug‘orish 103,2 ming gektarda joriy qilingan bo‘lib, jami suv tejovchi texnologiyalar tarkibida 12,6 foizni tashkil etadi. Ushbu ko‘rsatkich tomchilatib sug‘orish texnologiyasi hali umumiy tarkibda nisbatan kichik ulushga ega bo‘lsa-da, uning suvni bevosita o‘simlik ildiziga yetkazish, suv sarfini kamaytirish va hosildorlikni barqarorlashtirishdagi ahamiyati yuqori ekanini ko‘rsatadi. Yomg‘irlatib sug‘orish, diskret sug‘orish, egiluvchan quvurlar va egatga plyonka to‘shab sug‘orish texnologiyalari esa suv tejashning turli agrotexnik shakllari sifatida ekin turi, hududning iqlim sharoiti va sug‘orish tizimi xususiyatlariga qarab qo‘llanilmoqda.

Dronlar, IoT sensorlari, smart issiqxonalar, kosmik monitoring va haydovchisiz boshqariladigan texnikalar esa O‘zbekistonda hozircha ko‘proq innovatsion va pilot bosqichda rivojlanmoqda. Biroq ularning ahamiyati shundaki, ushbu texnologiyalar qishloq xo‘jaligida an’anaviy kuzatuv va tajribaga asoslangan boshqaruvdan real vaqt rejimidagi ma’lumotlar, masofaviy monitoring va avtomatlashtirilgan qaror qabul qilish tizimiga o‘tish imkonini beradi. Masalan, 100 dan ortiq dronning ekin monitoringi va agrotexnik vazifalarda qo‘llanilishi kelgusida dala ishlarini tezlashtirish, zararkunandalarga qarshi kurashish va o‘g‘itlash jarayonlarini aniq boshqarish imkoniyatini kengaytiradi.

Umuman olganda, O‘zbekiston qishloq xo‘jaligida aqlli texnologiyalarni tatbiq etishning hozirgi bosqichi ikki asosiy xususiyat bilan ajralib turadi. Birinchidan, keng qamrovli texnologik tatbiq asosan suv tejovchi sug‘orish va yerlarni lazerli tekislash yo‘nalishida kuzatilmoqda. Ikkinchidan, dronlar, IoT sensorlari, smart issiqxonalar, kosmik monitoring va avtomatlashtirilgan texnikalar kabi yuqori raqamli texnologiyalar bosqichma-bosqich sinovdan o‘tkazilmoqda va ayrim hududlarda amaliyotga kiritilmoqda. Kelgusida ushbu texnologiyalarni kengaytirish uchun hududlar kesimida raqamli infratuzilmani rivojlantirish, fermerlarning texnologik savodxonligini oshirish, servis xizmatlarini yo‘lga qo‘yish va aqlli agrotexnologiyalarni moliyalashtirish mexanizmlarini kuchaytirish muhim ahamiyat kasb etadi.

O‘zbekiston hududida aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etish holatini baholashda SWOT tahlilidan foydalanish mazkur jarayonning ichki imkoniyatlari va cheklovlarini, shuningdek, tashqi muhitdan kelib chiqadigan

rivojlanish imkoniyatlari hamda xavf-xatarlarni tizimli aniqlash imkonini beradi. Aqlli qishloq xo‘jaligi texnologiyalari O‘zbekiston sharoitida, avvalo, suv resurslaridan samarali foydalanish, ekin maydonlarini masofadan monitoring qilish, agrotexnik tadbirlarni aniq rejalashtirish, hosildorlikni oshirish va qishloq xo‘jaligi ishlab chiqarishida resurs tejamkorlikni ta’minlash bilan bog‘liq.

Tahlillar shuni ko‘rsatadiki, mamlakatda suv tejovchi texnologiyalar, lazerli yer tekislash, dronlardan foydalanish, kosmik monitoring, IoT sensorlari, smart issiqxonalar va raqamli agroplatformalarni joriy etish bo‘yicha dastlabki institutsional va amaliy asoslar shakllangan. Shu bilan birga, mazkur texnologiyalarni barcha hududlarda bir xil darajada keng tatbiq etish uchun moliyaviy, infratuzilmaviy, kadrlar, servis xizmatlari va raqamli savodxonlik bilan bog‘liq muammolar mavjud. Shuning uchun SWOT tahlili aqlli qishloq xo‘jaligi texnologiyalarini kengaytirish bo‘yicha strategik ustuvorliklarni belgilashda muhim amaliy ahamiyatga ega.

O‘zbekiston hududida aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etish bo‘yicha SWOT tahlili

SWOT elementi	Asosiy jihatlar	Izoh
Kuchli tomonlar	Qishloq xo‘jaligining milliy iqtisodiyotdagi yuqori ahamiyati	Qishloq xo‘jaligi oziq-ovqat xavfsizligi, bandlik, eksport va hududiy rivojlanishda muhim tarmoq hisoblanadi. Shu sababli aqlli texnologiyalarni joriy etish iqtisodiy jihatdan zarur va strategik ahamiyatga ega.
	Suv tejovchi texnologiyalar bo‘yicha amaliy tajribaning shakllangani	Tomchilatib sug‘orish, yomg‘irlatib sug‘orish, diskret sug‘orish, egiluvchan quvurlar va lazerli yer tekislash texnologiyalarining qo‘llanilishi aqlli agrotexnologiyalar uchun muhim asos yaratmoqda.
	Davlat tomonidan raqamlashtirish va resurs tejamkorlikka e’tibor kuchaygani	Qishloq xo‘jaligida suvdan foydalanish samaradorligini oshirish, raqamli boshqaruv, kosmik monitoring va integratsion platformalar bo‘yicha tashabbuslarning mavjudligi texnologik yangilanishni rag‘batlantiradi.
	Agroklasterlar va yirik fermer xo‘jaliklarining mavjudligi	Yirik xo‘jalik subyektlari zamonaviy texnologiyalarni joriy etish, xarajatlarni qoplash va texnologik tajribalarni kengaytirishda nisbatan yuqori imkoniyatga ega.
Zaif tomonlar	Aqlli texnologiyalarning yuqori xarajat talab qilishi	Sensorlar, dronlar, avtomatlashtirilgan sug‘orish tizimlari, smart issiqxonalar va raqamli monitoring vositalari ko‘plab kichik fermer xo‘jaliklari uchun moliyaviy jihatdan qimmat hisoblanadi.
	Fermerlarning raqamli savodxonligi va texnik ko‘nikmalari yetarli emasligi	Aqlli texnologiyalarni samarali ishlatish uchun nafaqat texnika, balki uni boshqarish, ma’lumotlarni tahlil qilish va natijaga asoslangan qaror qabul qilish ko‘nikmalari zarur.
	Ayrim hududlarda internet va raqamli infratuzilmaning cheklanganligi	IoT sensorlari, masofaviy monitoring, raqamli platformalar va mobil ilovalar samarali ishlashi uchun barqaror aloqa va raqamli infratuzilma zarur.
	Texnik servis va maslahat xizmatlarining yetarli rivojlanmagani	Aqlli texnologiyalarni joriy etishda uskunalarni o‘rnatish, sozlash, ta’mirlash va doimiy texnik qo‘llab-quvvatlash tizimi muhim ahamiyatga ega.
Imkoniyatlar	Suv tanqisligi sharoitida resurs tejamkor texnologiyalarga talabning ortishi	O‘zbekiston sharoitida suv resurslaridan samarali foydalanish muhim masala bo‘lib, aqlli sug‘orish va suv monitoringi texnologiyalariga ehtiyoj oshib bormoqda.
	Xalqaro tashkilotlar va xorijiy investorlar bilan hamkorlik imkoniyatlari	FAO, Jahon banki va boshqa xalqaro tashkilotlar bilan hamkorlik aqlli qishloq xo‘jaligi texnologiyalarini moliyalashtirish, tajriba almashish va pilot loyihalarni kengaytirish imkonini beradi.
	Kosmik monitoring, dronlar va	Masofadan monitoring qilish texnologiyalari yer va suv

SWOT elementi	Asosiy jihatlar	Izoh
	sun'iy intellekt texnologiyalarini kengaytirish	resurslari holatini aniqlash, ekinlar rivojlanishini kuzatish va agrotexnik tadbirlarni optimallashtirish imkonini beradi.
	Hududlar kesimida "aqlli agrohududlar"ni shakllantirish imkoniyati	Texnologik tayyorgarligi yuqori hududlarda pilot loyihalarni kengaytirish orqali bosqichma-bosqich aqlli qishloq xo'jaligi klasterlarini shakllantirish mumkin.
Tahdidlar	Iqlim o'zgarishi va suv resurslari tanqisligining kuchayishi	Suv taqchilligi, qurg'oqchilik, tuproq degradatsiyasi va sho'rlanish aqlli texnologiyalar joriy etilmasa, agrar ishlab chiqarish samaradorligiga salbiy ta'sir ko'rsatishi mumkin.
	Texnologiyalarga qaramlik va import uskunalarga bog'liqlik	Dronlar, sensorlar, avtomatlashtirilgan tizimlar va dasturiy mahsulotlarning katta qismi import qilinadigan bo'lsa, narx, servis va ehtiyot qismlar bo'yicha tashqi bog'liqlik kuchayishi mumkin.
	Raqamli tafovutning chuqurlashishi	Yirik agroklasterlar texnologiyalardan tez foydalanishi, kichik fermerlar esa moliyaviy va texnik cheklovlar sabab ortda qolishi mumkin.
	Ma'lumotlar xavfsizligi va boshqaruvdagi uzilishlar	Raqamli platformalar, sensorlar va monitoring tizimlarida ma'lumotlar xavfsizligi, tizimlarning uzluksiz ishlashi va axborot ishonchliligini ta'minlash muhim masala bo'lib qoladi.

SWOT tahlili natijalari shuni ko'rsatadiki, O'zbekistonda aqlli qishloq xo'jaligi texnologiyalarini joriy etish uchun muhim ichki salohiyat mavjud. Ayniqsa, qishloq xo'jaligining iqtisodiyotdagi o'rni, suv tejovchi texnologiyalarni joriy etish bo'yicha shakllangan tajriba, davlat tomonidan raqamlashtirishga e'tiborning kuchayishi va xalqaro hamkorlik imkoniyatlari bu jarayonning rivojlanishiga ijobiy ta'sir ko'rsatadi. Shu bilan birga, texnologiyalarning yuqori qiymati, fermerlarning raqamli ko'nikmalari yetarli emasligi, internet infratuzilmasidagi hududiy tafovutlar va servis xizmatlarining cheklanganligi aqlli qishloq xo'jaligi texnologiyalarini keng joriy etishda asosiy to'siqlar sifatida namoyon bo'lmoqda.

Mazkur tahlil asosida aytish mumkinki, O'zbekiston sharoitida aqlli qishloq xo'jaligini rivojlantirishda eng maqbul strategik yo'nalish bosqichma-bosqich joriy etish, ya'ni avvalo suv tejovchi texnologiyalar, lazerli yer tekislash, raqamli monitoring va dronlardan foydalanish kabi amaliy samarasi tez ko'rinadigan texnologiyalarni kengaytirishdan iborat bo'lishi lozim. Keyingi bosqichda esa IoT sensorlari, sun'iy intellektga asoslangan hosildorlik prognozlari, smart issiqxonalar, avtomatlashtirilgan texnika va yagona raqamli agroplatformalarni rivojlantirish maqsadga muvofiqdir.

XULOSA VA TAKLIFLAR

O'zbekiston hududida aqlli qishloq xo'jaligi texnologiyalarini tatbiq etish holatini tahlil qilish natijalari shuni ko'rsatadiki, mamlakat agrar sektorida raqamli va resurs tejamkor texnologiyalarni joriy etish jarayoni bosqichma-bosqich rivojlanmoqda. Xususan, suv tejovchi sug'orish texnologiyalari, lazerli yer tekislash, dronlar, kosmik monitoring, IoT sensorlari, smart issiqxonalar va raqamli agroplatformalar qishloq xo'jaligida samaradorlikni oshirishga xizmat qiluvchi muhim texnologik yo'nalishlar sifatida shakllanmoqda.

Tahlillar shuni ko'rsatadiki, O'zbekistonda aqlli qishloq xo'jaligi texnologiyalarining eng faol tatbiq etilayotgan yo'nalishi suv resurslarini tejash va sug'orish samaradorligini oshirish bilan bog'liq. Bu holat mamlakat qishloq xo'jaligining sug'oriladigan yerlar va suv resurslariga yuqori darajada bog'liqligi bilan

izohlanadi. Tomchilatib, yomg‘irlatib va diskret sug‘orish, egiluvchan quvurlar orqali sug‘orish, egatga plyonka to‘shab sug‘orish hamda lazerli yer tekislash texnologiyalarining kengayib borayotgani suvdan foydalanish samaradorligini oshirish va hosildorlikni barqarorlashtirishda muhim ahamiyat kasb etmoqda.

Shu bilan birga, dronlar, IoT sensorlari, smart issiqxonalar, sun’iy intellekt, kosmik monitoring va avtomatlashtirilgan texnika kabi yuqori raqamli texnologiyalar hali barcha hududlarda bir xil darajada ommalashmagan. Ular ko‘proq pilot loyihalar, alohida hududiy tashabbuslar va yirik xo‘jalik subyektlari darajasida joriy etilmoqda. Bu esa kelgusida ushbu texnologiyalarni kengaytirish uchun moliyaviy qo‘llab-quvvatlash, texnik servis, kadrlar tayyorlash va raqamli infratuzilmani rivojlantirish zarurligini ko‘rsatadi.

SWOT tahlili natijalari asosida aniqlanishicha, O‘zbekiston aqlli qishloq xo‘jaligi texnologiyalarini joriy etish bo‘yicha muhim imkoniyatlarga ega. Jumladan, davlat tomonidan agrar sohani modernizatsiya qilishga qaratilgan islohotlar, suv tejovchi texnologiyalar bo‘yicha amaliy tajriba, xalqaro hamkorlik loyihalari va raqamli agroplatformalarni shakllantirish tashabbuslari ushbu jarayonning kuchli tomonlari hisoblanadi. Biroq texnologiyalarning yuqori qiymati, kichik fermer xo‘jaliklarining moliyaviy imkoniyatlari cheklanganligi, raqamli savodxonlik darajasidagi tafovutlar va servis infratuzilmasining yetarli rivojlanmagani asosiy zaif jihatlar sifatida saqlanib qolmoqda.

Maqola natijalari asosida quyidagi ilmiy-amaliy takliflarni ilgari surish mumkin:

1. Hududlar kesimida aqlli qishloq xo‘jaligi texnologiyalarini joriy etish darajasini baholovchi indikatorlar tizimini ishlab chiqish zarur. Bunda har bir hudud bo‘yicha suv tejovchi texnologiyalar ulushi, raqamli infratuzilma holati, dron va sensorlardan foydalanish darajasi, fermerlarning raqamli savodxonligi, texnik servis mavjudligi va investitsion imkoniyatlar alohida baholanishi maqsadga muvofiq. Mazkur indikatorlar hududlar o‘rtasidagi tafovutlarni aniqlash va manzilli qo‘llab-quvvatlash choralarini ishlab chiqishga xizmat qiladi.
2. Suv tejovchi va aqlli sug‘orish texnologiyalarini joriy etishni ustuvor yo‘nalish sifatida kengaytirish lozim. O‘zbekiston sharoitida suv resurslari cheklanganligi sababli tomchilatib sug‘orish, yomg‘irlatib sug‘orish, diskret sug‘orish, tuproq namligini o‘lchovchi sensorlar va suv sarfini real vaqt rejimida nazorat qiluvchi raqamli tizimlarni keng qo‘llash muhim ahamiyatga ega. Bu suv sarfini kamaytirish, hosildorlikni barqarorlashtirish va iqlim o‘zgarishi sharoitida agrar ishlab chiqarish xavfsizligini ta’minlashga yordam beradi.
3. Fermer va agroklasterlar uchun raqamli savodxonlik hamda aqlli texnologiyalarni boshqarish bo‘yicha amaliy o‘quv dasturlarini yo‘lga qo‘yish kerak. Aqlli qishloq xo‘jaligi texnologiyalarining samarali ishlashi faqat texnika va uskunalar mavjudligiga emas, balki ulardan foydalanadigan mutaxassislarning bilim va ko‘nikmalariga ham bog‘liq. Shu sababli hududlarda fermerlar, agronomlar, suv xo‘jaligi mutaxassislari va agroklaster xodimlari uchun IoT sensorlari, dronlar, raqamli xaritalar, smart sug‘orish va ma’lumotlarga asoslangan qaror qabul qilish bo‘yicha qisqa muddatli o‘quv kurslarini tashkil etish zarur.

4. Dronlar, IoT sensorlari, smart issiqxonalar va avtomatlashtirilgan agrotexnikalarni joriy etish uchun imtiyozli moliyalashtirish mexanizmlarini kuchaytirish maqsadga muvofiq. Ushbu texnologiyalarning narxi nisbatan yuqori bo‘lgani sababli kichik fermer xo‘jaliklari ularni mustaqil xarid qilishda qiyinchiliklarga duch keladi. Shu bois aqlli agrotexnologiyalar uchun imtiyozli kreditlar, lizing, subsidiya, davlat-xususiy sheriklik va kooperatsiya asosida foydalanish mexanizmlarini kengaytirish lozim.
5. Qishloq xo‘jaligi ma’lumotlarini yagona raqamli agroplatformada integratsiya qilish zarur. Yer, suv, ekin, hosildorlik, subsidiyalar, kreditlar, texnika, agroxizmatlar va bozor narxlari bo‘yicha ma’lumotlarning yagona platformada jamlanishi fermerlar, davlat organlari, ilmiy muassasalar va investorlar uchun tezkor, shaffof va ishonchli axborot muhitini yaratadi. Bunday platforma aqlli qishloq xo‘jaligi texnologiyalarini keng joriy etish, resurslardan foydalanish samaradorligini nazorat qilish va strategik qarorlarni dalillarga asoslangan holda qabul qilish imkonini beradi.

Umuman olganda, aqlli qishloq xo‘jaligi texnologiyalarini tatbiq etish O‘zbekiston agrar sektorini raqobatbardosh, resurs tejamkor, ekologik barqaror va innovatsion rivojlanish yo‘liga olib chiqishning muhim omillaridan biridir. Mazkur texnologiyalarni tizimli va bosqichma-bosqich joriy etish orqali qishloq xo‘jaligida suv va yer resurslaridan foydalanish samaradorligini oshirish, hosildorlikni ko‘paytirish, ishlab chiqarish xarajatlarini kamaytirish, fermer xo‘jaliklarining raqamli salohiyatini kuchaytirish hamda mamlakat oziq-ovqat xavfsizligini mustahkamlash imkoniyati kengayadi.

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STUDYING INTERNATIONAL BUSINESS MANAGEMENT PRACTICES THROUGH THE GERMAN EXPERIENCE: THE CASE OF THE "PARTNERING IN BUSINESS WITH GERMANY" PROGRAM

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Abstract. *This article analyzes the academic and practical experience gained through participation in the "Partnering in Business with Germany" program, with a particular focus on international business management. The program was conducted in a hybrid format from February to April, followed by an in-person study visit to Germany from April 6 to April 24. The study applies a qualitative research design based on structured observation, reflective analysis, comparative interpretation, and thematic grouping of management practices observed during company visits, training sessions, networking activities, and institutional meetings. Special attention is given to the methodology and results of the study by identifying how German business practices reflect strategic planning, quality management, operational efficiency, innovation, sustainability, and intercultural cooperation. The findings suggest that the German experience provides valuable lessons for developing entrepreneurship, agribusiness, education-business cooperation, and innovation-oriented management practices in Uzbekistan.*

Keywords: *international business management, Germany, strategic management, methodology, business cooperation, innovation, agribusiness, intercultural communication, sustainability.*

Annotatsiya. *Mazkur maqolada "Partnering in Business with Germany" dasturida ishtirok etish orqali olingan ilmiy-amaliy tajriba xalqaro biznes menejmenti nuqtayi nazaridan tahlil qilinadi. Dastur fevral-aprel oylarida gibrid shaklda, Germaniyadagi bevosita tashrif esa 6–24-aprel kunlari davomida amalga oshirilgan. Tadqiqotda sifat yondashuvi, strukturali kuzatuv, reflektiv tahlil, qiyosiy talqin va tematik guruhlash usullaridan foydalanildi. Kompaniya tashriflari, treninglar, tarmoq aloqalari va institutsional uchrashuvlar asosida Germaniya biznes amaliyotlaridagi strategik rejalashtirish, sifat menejmenti, operatsion samaradorlik, innovatsiya, barqarorlik va madaniyatlararo hamkorlik masalalari o'rganildi.*

Kalit so'zlar: *xalqaro biznes menejmenti, Germaniya, strategik boshqaruv, metodologiya, biznes hamkorlik, innovatsiya, agrobiznes, madaniyatlararo kommunikatsiya, barqaror rivojlanish.*

Аннотация. *В данной статье анализируется академический и практический опыт, полученный в рамках участия в программе "Partnering in Business with Germany", с акцентом на международный бизнес-менеджмент. Программа проходила в гибридном формате с февраля по апрель, а очный визит*

в Германию состоялся с 6 по 24 апреля. В исследовании применён качественный подход, основанный на структурированном наблюдении, рефлексивном анализе, сравнительной интерпретации и тематической группировке управленческих практик, изученных во время визитов в компании, тренингов, сетевых мероприятий и институциональных встреч. Особое внимание уделено методологии и результатам исследования, включая стратегическое планирование, управление качеством, операционную эффективность, инновации, устойчивое развитие и межкультурное сотрудничество.

Ключевые слова: *международный бизнес-менеджмент, Германия, стратегическое управление, методология, деловое сотрудничество, инновации, агробизнес, межкультурная коммуникация, устойчивое развитие.*

I. INTRODUCTION

In the context of globalization, international business management has become one of the key areas of economic development, entrepreneurship, and institutional transformation. Companies increasingly operate beyond national borders, interact with foreign partners, adopt international standards, and develop management systems that respond to global competition. Therefore, the practical study of international business environments is highly important for researchers, students, entrepreneurs, and policymakers.

Germany is widely recognized as one of Europe's leading economies and a global center of industrial development, technological innovation, quality management, and export-oriented business. German companies are often associated with long-term strategic planning, operational discipline, strong organizational culture, sustainability, and cooperation between education, industry, and public institutions. These features make Germany an important case for studying international business management in practice.

The "Partnering in Business with Germany" program provided an opportunity to examine these issues from both academic and practical perspectives. The program was organized in a hybrid format from February to April, followed by an in-person visit to Germany from April 6 to April 24. During the program, participants engaged in company visits, training sessions, reflection meetings, networking events, and cultural activities. These activities allowed participants to observe how German organizations manage business processes, develop partnerships, implement innovation, and communicate across cultural and institutional boundaries.

The relevance of this study is connected with the growing need to strengthen international business competence in Uzbekistan. As the country seeks to expand entrepreneurship, agribusiness, export potential, innovation, and international cooperation, the study of advanced business management practices becomes increasingly important. From this perspective, the German experience offers practical lessons that may support the development of competitive and sustainable business models in Uzbekistan.

II. LITERATURE REVIEW

International business management has been widely discussed in academic literature. Porter's theory of competitive advantage emphasizes that national and firm-level success in international markets depends on innovation, productivity, quality, and the ability to build efficient business systems. This approach is relevant to the German business model, where industrial competitiveness is closely connected with innovation, skills development, and systematic management.

Hofstede's cultural dimensions theory highlights the importance of understanding cultural differences in international business. Organizations operating internationally must consider different communication styles, decision-making traditions, attitudes toward hierarchy, time management, and cooperation. In this sense, intercultural competence is an essential element of international business management. Modern studies also show that international business management is not limited to market entry and profit generation. It increasingly includes sustainability, corporate responsibility, innovation, knowledge transfer, and long-term value creation. Companies are expected to balance economic performance with social and environmental considerations. German business practice is often associated with this broader understanding of management, particularly through its emphasis on quality, efficiency, technical competence, and responsible production.

In the context of emerging economies, international business management is especially important for strengthening entrepreneurship, attracting investment, improving export competitiveness, and developing human capital. For Uzbekistan, the study of international management practices can contribute to the modernization of business education, the development of agribusiness, and the growth of innovation-driven enterprises.

III. RESEARCH METHODOLOGY

This article applies a qualitative research methodology because the main objective is to interpret practical management experience rather than measure a single numerical indicator. The research is based on the author's participation in the "Partnering in Business with Germany" program. The program consisted of two stages: a hybrid preparatory and learning phase from February to April, and an in-person study visit to Germany from April 6 to April 24. This two-stage structure made it possible to combine theoretical preparation with direct observation of real business practices.

The empirical basis of the research includes observations collected during company visits, institutional meetings, training sessions, reflection discussions, networking events, and cultural learning activities. During these activities, attention was paid to how German organizations plan operations, communicate with partners, manage quality, use innovation, organize human resources, and maintain international cooperation. The observations were not treated as isolated impressions; instead, they were grouped into analytical themes relevant to international business management.

The research design included four methodological steps. First, the program activities were observed from the perspective of international business management. Second, the observed practices were classified into thematic categories such as

strategic management, quality management, education-business cooperation, intercultural communication, innovation, and sustainability. Third, these categories were compared with major concepts from the literature on international business and management. Fourth, the relevance of the observed German practices for Uzbekistan was assessed, particularly in relation to entrepreneurship, agribusiness, business education, and innovation-driven development.

The study used the following analytical framework: input, process, observed management practice, and potential application. The input stage included the hybrid training and preparatory sessions. The process stage included direct participation in company visits, meetings, and discussions in Germany. The observed management practice stage focused on identifying concrete business principles, such as structured planning, punctual communication, quality orientation, and cooperation with institutions. The potential application stage considered how selected lessons could be adapted to the economic and business context of Uzbekistan.

The study has certain limitations. Since it is based on a study visit and qualitative observation, it does not claim to measure the entire German business system statistically. The findings represent analytical reflections based on program participation and observed practices. However, this type of qualitative approach is appropriate for identifying practical lessons, research directions, and management insights that may be useful for future empirical studies and policy-oriented research.

Table 1. Methodological structure of the research

Stage	Data source	Method used	Purpose
1. Preparation	Hybrid program sessions, February-April	Documented learning and reflection	To understand key themes before the visit
2. Field exposure	In-person visit to Germany, April 6-24	Structured observation	To observe real business practices
3. Analysis	Company visits, meetings, networking, reflections	Thematic grouping and comparison	To classify management practices
4. Interpretation	Observed practices and literature concepts	Comparative analysis	To identify relevance for Uzbekistan

IV. ANALYSIS AND MAIN RESULTS

The results of the study show that the German business management experience is based on several interconnected principles. These principles are not limited to individual company performance, but reflect a broader institutional culture of planning, quality, responsibility, cooperation, and continuous improvement. The most important results are presented below.

First, the program demonstrated the importance of strategic planning in international business management. German companies and institutions tend to organize activities through clear goals, defined roles, time-based planning, and responsibility distribution. This approach reduces uncertainty and supports effective coordination among different departments, partners, and stakeholders. For Uzbekistan, this result indicates the need to strengthen planning discipline in small and medium-sized enterprises, agribusiness projects, and educational institutions.

Second, quality management was observed as a central component of competitiveness. In the German context, quality is not treated only as the final condition of a product or service. It is part of the full management chain, including production planning, communication, logistics, customer relations, employee skills, and organizational culture. This result is important for enterprises in Uzbekistan that seek to improve export readiness and international credibility.

Third, the study identified strong cooperation between education, business, and institutions as a key factor of sustainable development. The German experience shows that practical learning, company engagement, and institutional support can help develop skilled human capital and innovation-oriented enterprises. This finding is especially relevant for agribusiness education, where students and entrepreneurs need both theoretical knowledge and exposure to real market practices.

Fourth, intercultural communication appeared as a major factor in international business cooperation. Professional communication, punctuality, clarity, respect for agreements, and trust-building were observed as important features of German business culture. This result suggests that entrepreneurs and managers from Uzbekistan should develop not only technical business knowledge, but also intercultural competence when cooperating with foreign partners.

Fifth, innovation and sustainability were observed as integrated elements of modern management. German business practice often connects operational efficiency with technology adoption, responsible resource use, and long-term value creation. This result is highly relevant to Uzbekistan's agribusiness and entrepreneurship sectors, where sustainability and innovation can increase competitiveness and open access to international markets.

Table 2. Main results of the study

Result area	Observed German practice	Management interpretation	Relevance for Uzbekistan
Strategic management	Clear planning, structured processes, defined responsibilities	Management effectiveness depends on systematic organization	Useful for SMEs, startups, and agribusiness planning
Quality management	Strong attention to reliability and continuous improvement	Quality is part of the whole management system	Supports export readiness and customer trust
Education-business cooperation	Interaction between training, companies, and institutions	Applied learning strengthens human capital	Relevant for IAU/RAU agribusiness education and youth entrepreneurship
Intercultural communication	Punctuality, clarity, professionalism, and trust	International cooperation requires cultural competence	Helps Uzbek entrepreneurs work with foreign partners
Innovation and sustainability	Technology use, efficiency, and responsible resource management	Long-term value creation is a management priority	Important for sustainable agribusiness and innovation projects

The overall result of the research is that Germany's international business management model can be understood as a combination of disciplined planning, quality orientation, institutional cooperation, intercultural competence, and innovation-based sustainability. These elements support the competitiveness of companies and create a reliable environment for long-term business cooperation.

For Uzbekistan, the findings imply that international business management should be developed not only through classroom education, but also through applied learning, study visits, company-based projects, mentorship, and cooperation with foreign institutions. In the field of agribusiness, this approach may help students and entrepreneurs understand global value chains, export requirements, quality standards, and sustainable production models.

The research also indicates that future PhD-level studies may examine the transferability of selected German business management practices to the Uzbek context. Such studies may focus on agribusiness clusters, SME internationalization, education-business cooperation, export-oriented entrepreneurship, or innovation management in emerging markets.

V. CONCLUSION AND RECOMMENDATIONS

The academic and practical visit to Germany provided valuable insights into international business management. The "Partnering in Business with Germany" program demonstrated how management theory can be connected with real business practice. Through the hybrid learning phase and the in-person visit from April 6 to April 24, the program helped reveal the importance of strategy, quality, innovation, intercultural communication, and sustainability in international business.

The German experience shows that successful business management requires more than financial resources. It requires disciplined planning, strong organizational culture, professional communication, skilled human capital, and continuous improvement. These principles are highly relevant for Uzbekistan as the country continues to develop entrepreneurship, agribusiness, education, and international economic cooperation.

Based on the findings, the following recommendations are proposed:

- develop more practical international business management programs for students, researchers, and entrepreneurs;
- strengthen cooperation between universities, companies, and business-support institutions;
- introduce training programs on quality management, strategic planning, and intercultural business communication;
- adapt selected German business management practices to Uzbekistan's entrepreneurship and agribusiness sectors;
- promote innovation, sustainability, and responsible management in business education;
- support young entrepreneurs in gaining international exposure and building foreign partnerships;
- encourage applied research based on international study visits and business exchange programs.

In conclusion, the German experience offers valuable academic and practical lessons for understanding international business management. The knowledge gained through the "Partnering in Business with Germany" program can contribute to the

development of more competitive, innovative, and internationally connected business practices in Uzbekistan.

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DIGITALIZATION OF AGRICULTURE IN UZBEKISTAN: ECONOMIC EFFICIENCY OF SMART AGRICULTURE TECHNOLOGIES

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Abstract. *This paper examines the digitization of Uzbekistan's agriculture and evaluates the economic impact of Smart Agriculture technologies. This paper identifies the modern digital technologies' role in agriculture in Uzbekistan, their influence on the efficiency of production, and possible future development. The methods of statistical analysis, comparative analysis, and descriptive analysis were applied. Uzbek figures were compared to the figures of the Netherlands, the USA, and Israel and Japan in particular.*

The study concluded that the modern technologies that incorporate smart agricultural IoT (internet of things) sensors, artificial intelligence and drone technology, along with smart agriculture GPS (global positioning system) and water-efficient irrigation technologies, improve the efficiency of resource usage in agriculture and considerably reduce water usage, increase production and improve cost efficiency of production. Furthermore, challenges of Smart Agriculture technology in Uzbekistan were identified in the digital and financial infrastructure and the technological literacy of the farmers.

The article offers practical measures that support the digitalization of agriculture in Uzbekistan by the usage of international best practices and the promotion of innovative projects and the training of farmers in digital technologies.

Keywords: *Smart Agriculture, digitalization, agriculture, IoT, artificial intelligence, precision farming, agro-innovation, water-saving technologies.*

Annotatsiya. *Ushbu maqolada O‘zbekiston qishloq xo‘jaligini raqamlashtirish jarayoni hamda* ***Smart Agriculture (Aqlli qishloq xo‘jaligi)*** *texnologiyalarining iqtisodiy samaradorligi tahlil qilinadi. Tadqiqotda zamonaviy raqamli texnologiyalarning O‘zbekiston qishloq xo‘jaligidagi o‘rni, ularning ishlab chiqarish samaradorligiga ta’siri va istiqboldagi rivojlanish imkoniyatlari baholangan. Tadqiqotda statistik tahlil, qiyosiy tahlil va tavsifiy tahlil usullaridan foydalanilgan. O‘zbekistonning ko‘rsatkichlari Niderlandiya, AQSh, Isroil va Yaponiya kabi raqamli qishloq xo‘jaligi rivojlangan davlatlar tajribasi bilan taqqoslangan.*

Tadqiqot natijalari shuni ko‘rsatdiki, ***IoT (Internet of Things)*** *sensorlari, sun’iy intellekt, dron texnologiyalari, GPS (Global Positioning System) asosidagi aniq dehqonchilik hamda suvni tejovchi sug‘orish tizimlarini o‘z ichiga olgan Smart Agriculture texnologiyalari qishloq xo‘jaligida resurslardan foydalanish samaradorligini sezilarli darajada oshiradi, suv sarfini kamaytiradi, hosildorlikni ko‘paytiradi va ishlab chiqarish xarajatlarini optimallashtiradi. Shu bilan birga, O‘zbekistonda ushbu texnologiyalarni joriy etishga to‘sqinlik qilayotgan asosiy omillar sifatida raqamli va moliyaviy infratuzilmaning yetarli darajada rivojlanmaganligi hamda fermerlarning raqamli texnologiyalar bo‘yicha bilim va ko‘nikmalarining cheklanganligi aniqlandi.*

Maqolada xalqaro ilg‘or tajribalarni joriy etish, innovatsion loyihalarni qo‘llab-quvvatlash hamda fermerlarning raqamli kompetensiyalarini rivojlantirish orqali O‘zbekiston qishloq xo‘jaligini raqamlashtirishni jadallashtirish bo‘yicha amaliy tavsiyalar ishlab chiqilgan.

Kalit so‘zlar: *aqlli qishloq xo‘jaligi, raqamlashtirish, qishloq xo‘jaligi, IoT, sun’iy intellekt, aniq dehqonchilik, agroinnovatsiyalar, suvni tejovchi texnologiyalar.*

Аннотация. *В данной статье рассматривается процесс цифровизации сельского хозяйства Узбекистана и оценивается экономическая эффективность технологий Smart Agriculture (умного сельского хозяйства). Исследование направлено на выявление роли современных цифровых технологий в развитии сельского хозяйства Узбекистана, оценку их влияния на эффективность сельскохозяйственного производства, а также определение перспектив дальнейшего развития отрасли. В работе использованы методы статистического, сравнительного и описательного анализа. Показатели Узбекистана сопоставлены с опытом стран, являющихся мировыми лидерами в области цифрового сельского хозяйства, включая Нидерланды, США, Израиль и Японию.*

Результаты исследования показывают, что внедрение технологий Smart Agriculture, включая датчики IoT (Интернета вещей), искусственный интеллект, беспилотные летательные аппараты (дроны), системы точного земледелия на основе GPS (глобальной системы позиционирования) и водосберегающие технологии орошения, способствует повышению эффективности использования ресурсов, значительному сокращению потребления воды, росту урожайности и снижению производственных затрат.

Вместе с тем выявлены основные препятствия для широкого внедрения технологий умного сельского хозяйства в Узбекистане, среди которых недостаточное развитие цифровой и финансовой инфраструктуры, а также ограниченный уровень цифровой грамотности фермеров.

В статье предложены практические рекомендации, направленные на ускорение цифровизации сельского хозяйства Узбекистана посредством внедрения передового международного опыта, поддержки инновационных проектов и повышения квалификации фермеров в области цифровых технологий.

Ключевые слова: *умное сельское хозяйство, цифровизация, сельское хозяйство, Интернет вещей (IoT), искусственный интеллект, точное земледелие, агроинновации, водосберегающие технологии.*

JEL: Q16, O33, C88

INTRODUCTION

Agriculture is one of the strategic sectors of the economy of each country. Especially in developing countries, this sector is of great importance in providing the population with food products, creating employment and increasing export potential. Agriculture also occupies one of the leading positions in the economy of Uzbekistan. In recent years, the country has been implementing large-scale reforms aimed at modernizing the agricultural sector, increasing production efficiency, and introducing modern technologies. In this regard, the digitalization process is emerging as one of the main factors in the development of agriculture.

Traditional agricultural methods have problems such as inefficient use of water resources, difficulties in predicting yields, high production costs, and the impact of climate change. Smart Agriculture technologies are an important solution to solving these problems. Smart Agriculture is a system for managing agricultural processes based on artificial intelligence, the Internet of Things (IoT), drones, GPS monitoring, sensor systems, and big data. With the help of these technologies, farmers have the opportunity to use resources more efficiently, increase productivity, and reduce production costs.

World experience shows that the use of digital technologies in developed countries has significantly increased agricultural efficiency. For example, countries such as the Netherlands, the USA, Japan and Israel are widely using precision farming, automated irrigation systems and artificial intelligence-based monitoring systems. As a result, limited land and water resources are being used with high efficiency in these countries.

Uzbekistan has also been taking significant steps towards the digitalization of agriculture in recent years. The introduction of electronic land monitoring, agro-platforms, water-saving irrigation technologies and remote monitoring systems is creating new opportunities in the agricultural sector. However, there are some problems related to the level of technological knowledge of farmers, infrastructure capabilities and financial resources in the widespread introduction of digital technologies.

The main objective of this study is to analyze the development status of Smart Agriculture technologies in Uzbekistan and assess their economic efficiency. During

the study, the experience of Uzbekistan is compared with international practice, the impact of digitalization on agricultural production, existing problems and future development directions are studied.

LITERATURE REVIEW

In recent years, the digitalization of agriculture has become one of the main goals of agricultural policies at global levels. The concepts of Smart Agriculture, Precision Agriculture, and Agriculture 4.0 involve in their visions an increase in production efficiency due to the implementation of modern information and communication technologies in agriculture. In scientific research, such technologies as artificial intelligence (AI), the Internet of Things (IoT), GPS, GIS, drones, remote sensing technologies, and Big Data analytic systems are presented as effective ones in terms of managing agricultural resources, forecasting harvests, and optimizing costs (Wolfert et al., 2017; Liakos et al., 2018; Klerkx et al., 2019). These technologies allow farmers to ensure effective data analysis in real-time and make appropriate decisions based on that analysis.

The economic efficiency of smart agricultural technologies has been studied by many researchers. Zhang et al. (2002) and Lowenberg-DeBoer and Erickson (2019) stress that precision farming technologies help cut fuel, mineral fertilizer, and water consumption and improve productivity. Recent studies highlight the importance of digital technologies, such as crop monitoring, disease detection, and irrigation under artificial intelligence and Internet of Things control, in decreasing production costs and increasing farm profits (Papadopoulos et al., 2024; Kumar et al., 2024; Assimakopoulos et al., 2024). The Food and Agriculture Organization of the United Nations and the Organization for Economic Co-operation and Development acknowledge digital technologies' role in contributing to food security, resource conservation, and sustainable agricultural development.

Large-scale reforms are also being implemented in Uzbekistan to modernize and digitize agriculture. In particular, special attention is paid to increasing production efficiency through the introduction of electronic land monitoring, water-saving irrigation systems, agro-platforms and remote monitoring technologies. The reports of the World Bank, FAO and Asian Development Bank indicate that the efficient use of water resources, adaptation of agriculture to climate change and the widespread introduction of digital technologies in Uzbekistan are priority areas of the country's agrarian policy. At the same time, the digital literacy of farmers, the high cost of technologies and the insufficient development of digital infrastructure in rural areas are indicated as the main factors hindering the widespread introduction of smart technologies.

An analysis of the existing scientific literature shows that although the technical advantages and environmental efficiency of smart agricultural technologies have been widely studied, there are relatively few studies devoted to a comprehensive assessment of their economic efficiency in the conditions of Uzbekistan. In particular, there is a lack of scientific research assessing the investment efficiency of the introduction of digital technologies, the impact on production costs, the level of water saving and the

long-term impact on productivity. Therefore, this study serves to fill the existing scientific gap by analyzing the development status of Smart Agriculture technologies in Uzbekistan, assessing their economic efficiency, and comparing them with international experience.

METHODS

This study aims to assess the process of digitalization of agriculture in Uzbekistan, in particular, the economic efficiency of Smart Agriculture technologies. The study examined the level of use of modern digital solutions in agriculture, their production efficiency, resource utilization capabilities, and comparison with international experience. A comprehensive approach was chosen as the research methodology, using statistical analysis, comparative analysis, descriptive analysis, and scientific literature review methods.

The main database of the study was formed by reliable international and national statistical sources. Data on Uzbekistan were obtained from official data published by the National Statistics Committee of the Republic of Uzbekistan, the Ministry of Agriculture, Invest Uzbekistan, and state programs. For international comparison, data from the Food and Agriculture Organization of the United Nations (FAO), the World Bank, the Organization for Economic Cooperation and Development (OECD), and international agricultural technology studies were used.

The period of 2018–2025 was selected as the research period. The main reason for choosing this period is that it was during these years that Uzbekistan implemented large-scale reforms aimed at digitizing economic sectors, developing electronic management systems, and introducing innovative technologies in agriculture. At the same time, this period is also considered a stage of rapid development of artificial intelligence, IoT devices, and automated agricultural technologies internationally.
The study analyzed the following technologies as key elements of the Smart Agriculture concept:

Table-1. Main directions of Smart Agriculture technologies.

Technology	Application	Expected economic efficiency
IoT sensors	Monitoring soil moisture and temperature	Reducing water and fertilizer consumption
Drone technologies	Monitoring crop fields	Reducing labor costs
GPS systems	Precision farming processes	Saving fuel and resources
Artificial intelligence	Yield forecasting and analysis	Improving decision-making quality
Satellite monitoring	Monitoring the condition of the soil and crops	Reducing crop losses

Several analytical methods were used during the study. First, descriptive statistical analysis was used to study the dynamics of agricultural production indicators, the introduction of water-saving technologies, and the use of digital services in Uzbekistan. This method identified the current state, development trends, and key changes.

The second method was comparative analysis. The level of development of Uzbekistan in Smart Agriculture was compared with the experience of countries that widely use digital technologies in agriculture. In particular, the Netherlands, the USA, Japan, and Israel were selected. The reason for choosing these countries is that they have leading experience in the effective use of limited natural resources, achieving high yields, and using innovative agricultural technologies.

In addition, the study used graphical and tabular analysis methods. With the help of graphs, changes over time, differences between countries, and the economic impact of digital technologies were visually represented.

The methodological basis of the study was the model "digital technologies → resource efficiency → production volume → economic result". Through this approach, not only the technical but also the economic effectiveness of Smart Agriculture technologies was assessed. For example, the reduction of water consumption through water-saving irrigation systems, the increase in productivity through sensor technologies, and the reduction of production costs through digital monitoring were analyzed.

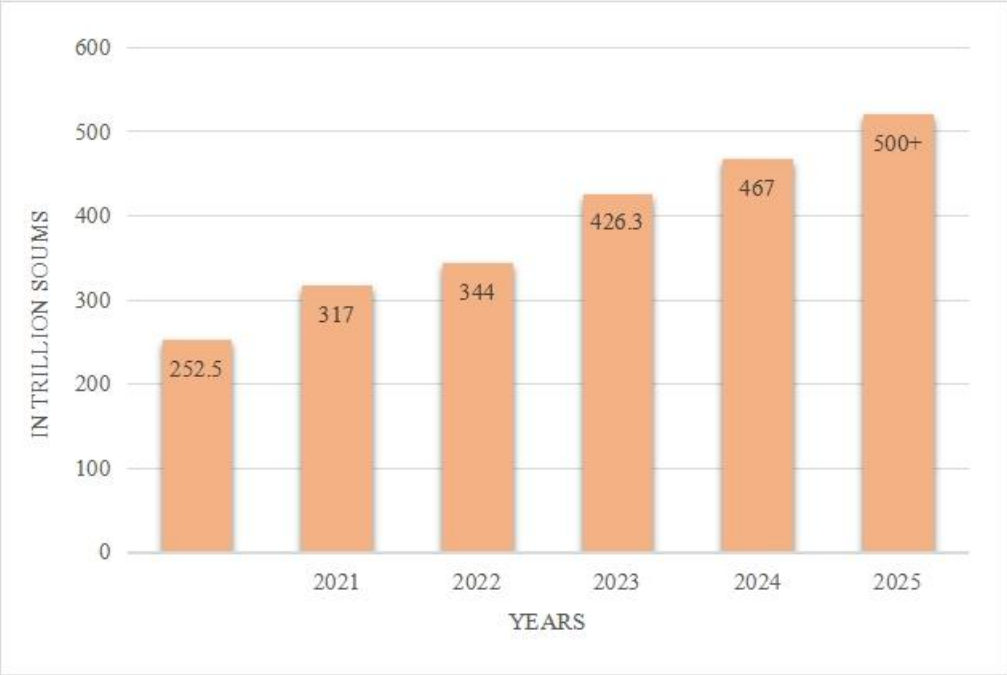
The study also conducted a qualitative analysis to identify existing problems and determine future development directions. This took into account the level of digital literacy of farmers, the cost of technologies, infrastructure capabilities, and state support mechanisms.

In general, the chosen methodological approach allows for a comprehensive assessment of the current state of Smart Agriculture technologies in Uzbekistan, comparison with international experience, and the development of effective development strategies in this area.

RESULTS

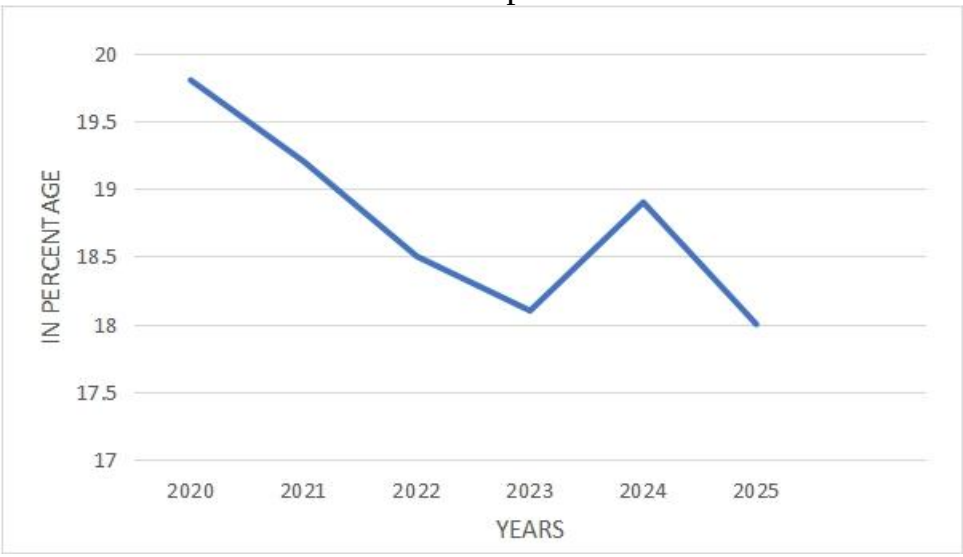
The results of the study show that the process of digitization of agriculture in Uzbekistan has been developing significantly in recent years. The use of modern technologies in the agricultural sector serves not only to improve production processes, but also to effectively use resources, improve product quality and strengthen the competitiveness of agricultural products. Agriculture in Uzbekistan is one of the important sectors of the country's economy, and the introduction of digital technologies in it is considered one of the main directions of sustainable development.

The analysis shows that a number of projects related to digitization in the agricultural sector were implemented in Uzbekistan during 2020–2025 (graphic 2). In particular, work on the introduction of electronic land monitoring systems, agrocluster management platforms, remote monitoring tools, and water-saving technologies has been expanded. These processes allow for the transition from traditional management methods in agriculture to a data-based management system.



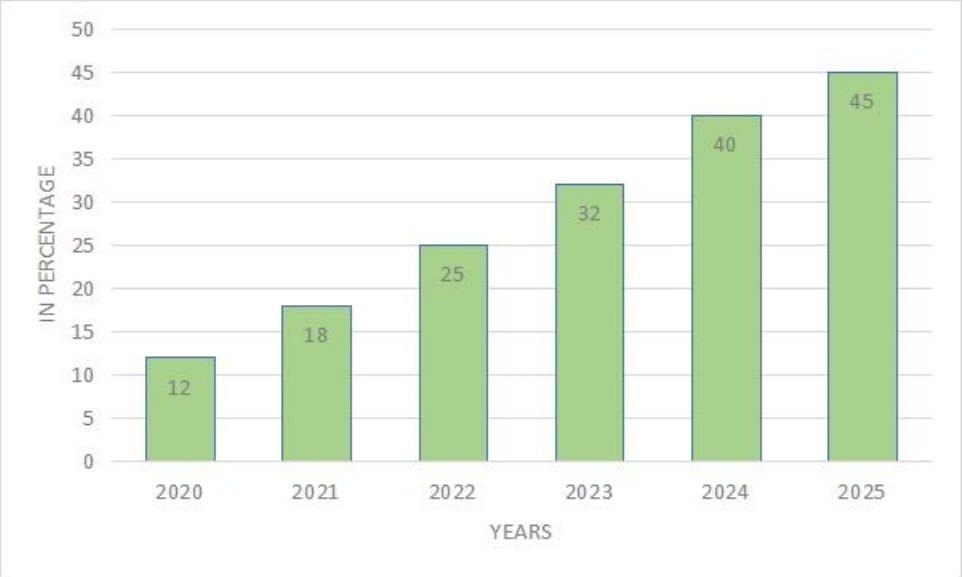
Graphic -1. Main economic indicators of the agricultural sector in Uzbekistan (2020–2025).

The graphic 1 shows that the volume of agricultural production in Uzbekistan during 2020–2025 has shown a consistent growth trend. In particular, the volume of production, which amounted to 252.5 trillion soums in 2020, is projected to reach 426.3 trillion soums in 2023, and more than 500 trillion soums by 2025. This growth indicates an increase in production efficiency as a result of reforms being implemented in the agricultural sector, modernization of production processes, introduction of innovative and digital technologies, as well as measures to support farms by the state. This trend confirms that the stable growth of agricultural production serves to strengthen the country's food security, expand export potential, and further increase the importance of the agricultural sector in economic development.



Graphic-2. Dynamics of changes in the share of agriculture in gross domestic product (GDP) in Uzbekistan during 2020–2025.

The graphic 2 shows the dynamics of changes in the share of agriculture in gross domestic product (GDP) in Uzbekistan during 2020–2025. As can be seen from the graph, the sector's share in GDP decreased from 19.8 percent in 2020 to 18.1 percent in 2023, but recovered to 18.9 percent in 2024. This situation indicates that the strategic importance of agriculture in the economy remains, while structural changes are taking place in the structure of the economy as a result of the rapid development of other sectors, such as industry and services. Also, the reforms being implemented in the agricultural sector to digitize, introduce innovative technologies, and increase production efficiency are contributing to the sustainable development of the sector.



Graphic-3. Coverage of water-saving technologies in agriculture.

The graphic 3 data shows that the scale of implementation of water-saving technologies in Uzbekistan has been steadily expanding during 2020-2025. In particular, if in 2020 the share of areas covered by these technologies was 12 percent, by 2025 this figure reached 45 percent. Such positive dynamics is the result of state programs and investment projects implemented to widely introduce drip irrigation, sprinkler irrigation and other modern irrigation methods. The use of water-saving technologies helps to reduce irrigation water consumption, improve land reclamation, and increase the productivity of agricultural crops. At the same time, these technologies are an important component of the Smart Agriculture concept and play a significant role in ensuring the digitalization of the agricultural sector and rational use of resources. As can be seen from the data, the volume of agricultural production has increased from year to year. At the same time, the share of agriculture in the overall economy has remained relatively stable. This indicates that other sectors of the economy are also developing. One of the most important results is the increase in the coverage of water-saving technologies. Because in the conditions of Uzbekistan, the efficient use of water resources is a decisive factor for the sustainability of agriculture.

An important indicator in assessing the economic efficiency of Smart Agriculture technologies is the reduction of water, labor and production costs. With the

help of modern sensor systems and automated irrigation technologies, farmers have the opportunity to obtain accurate information about the condition of crops.

Compared to international experience, Uzbekistan still lags behind developed countries in the use of Smart Agriculture technologies. However, reforms implemented in recent years are helping to reduce this gap. In particular, the experience of the Netherlands and Israel widely uses water management, automated greenhouses, and precision farming systems.

Table-2. International comparison of the use of Smart Agriculture technologies.

Country	Precision farming level	IoT and sensor use	Water saving technologies
Netherlands	Very high	Widespread	Above 90%
USA	High	Widespread	High
Israel	High	Widespread	Very high
Japan	High	Developed	High
Uzbekistan	Developing	Early-growing	Increasing

This table compares the level of use of Smart Agriculture technologies in different countries. While in developed countries digital technologies have become an integral part of agricultural production, in Uzbekistan this process is at the stage of active development.

The results of the study show that Smart Agriculture technologies are creating a significant economic opportunity for Uzbek agriculture. For example, precise irrigation systems can reduce water consumption by 30-50 percent, while sensor technologies can increase the efficiency of fertilizer use. In addition, rapid monitoring of crop areas through drone and satellite monitoring can help reduce yield losses.

Table-3. Economic impact of Smart Agriculture technologies.

Technology	Key result	Efficiency
Drip irrigation	Reduce water consumption	30–50% savings
IoT sensors	Precise monitoring	20–35% resource savings
Drones	Crop control	Reduce labor costs
AI systems	Prediction	Increase productivity

The table shows the impact of Smart Agriculture technologies on agricultural production efficiency. These technologies create opportunities for farms to reduce costs and improve production results.

Overall, the research results show that the process of digitization of agriculture in Uzbekistan is developing positively. Although the use of Smart Agriculture technologies is not yet fully developed, the existing results indicate that this direction will play an important role in increasing the future competitiveness of the country's agricultural sector.

DISCUSSION

The results of this study show that the process of digitization of agriculture in Uzbekistan has great potential for increasing the efficiency of the agricultural sector. The introduction of Smart Agriculture technologies is helping to transfer agricultural production processes from traditional management methods to a modern data-based management system. As shown in the results of the study, the use of water-saving technologies, remote monitoring systems, IoT devices, and precision farming elements is creating opportunities for efficient use of resources.

Agriculture in Uzbekistan is a sector that is largely dependent on natural resources, especially water resources. In the context of water scarcity and climate change in the country, increasing production efficiency has become a pressing issue. Therefore, one of the greatest advantages of Smart Agriculture technologies is the ability to save water and other production resources. For example, using drip irrigation and automated irrigation systems, it is possible to reduce water consumption and at the same time increase crop yields. This ensures not only economic efficiency, but also environmental sustainability.

When comparing the results of the study with the experience of developed countries, it was found that Uzbekistan still has great potential for development in this area. In particular, the experience of the Netherlands shows that digital technologies, automated greenhouses and precise control systems can be used to achieve high yields even in conditions of limited land. The experience of Israel can serve as an important example for Uzbekistan in water resource management and the development of innovative irrigation technologies.

At the same time, there are a number of problems in the widespread introduction of Smart Agriculture technologies in Uzbekistan. The first problem is the insufficient formation of farmers' knowledge and skills in the use of digital technologies. The digitalization process is slowing down due to the fact that many small and medium-sized farms do not fully understand the advantages of modern technologies or do not have the opportunity to use them.

The second problem is the high cost of introducing technologies. IoT sensors, drones, artificial intelligence systems and automated equipment require initial investments. It can be especially difficult for small farms to independently purchase such technologies. Therefore, it is necessary to strengthen the mechanisms for state subsidies, preferential loans and support for innovative projects.

The third problem is related to the level of development of digital infrastructure in rural areas. For Smart Agriculture technologies to work effectively, there must be a stable Internet connection, modern communication tools and technical support systems. The limited availability of these opportunities in some remote areas hinders the introduction of digital technologies.

In addition, it is important to strengthen cooperation between higher education institutions, research centers and agricultural enterprises. Training specialists in Smart Agriculture, organizing practical training for students and farmers, and introducing scientific developments into production will serve the development of this sector.

Based on the results of the study, the following strategic directions can be proposed for Uzbekistan. First, it is necessary to establish digital agriculture centers based on the climatic and production characteristics of each region. These centers can provide practical assistance to farmers in selecting technologies, using them and analyzing results.

Secondly, it is necessary to develop the production of local agrotechnology's. Currently, many modern technologies are imported, which increases their cost. By expanding local production, technologies can be made more accessible and affordable for farmers.

Thirdly, it is important to develop an agricultural database. Creating analytical systems based on Big Data on yield, weather conditions, soil conditions and market demand will improve farmers' decision-making.

In general, Smart Agriculture technologies are an important tool for modernizing Uzbek agriculture, increasing its competitiveness and ensuring its sustainable development. Despite the existing problems, the continuation of the digitalization process will create new economic opportunities in the agricultural sector and help strengthen Uzbekistan's position in the international agricultural market.

CONCLUSION

The results of this study show that the digitalization of agriculture and the introduction of Smart Agriculture technologies in Uzbekistan are an important strategic direction for increasing the efficiency of the agricultural sector, rational use of resources, and modernization of production processes. With the help of modern digital technologies, there is an opportunity to reduce the problems of water scarcity, high production costs, difficulties in managing yields, and climate change in agriculture.

During the study, the experience of Uzbekistan was compared with the experience of developed countries. The results showed that while Smart Agriculture technologies have become an integral part of agriculture in countries such as the Netherlands, the USA, Japan, and Israel, this process is still at the development stage in Uzbekistan. Nevertheless, in recent years, the expansion of water-saving irrigation systems, electronic monitoring, agroplatforms, and digital management systems has yielded positive results.

Based on the analysis, it was determined that the use of Smart Agriculture technologies serves to reduce water consumption, increase productivity, optimize production costs, and improve farmers' decision-making capabilities. In particular, IoT sensors, drones, GPS systems, and artificial intelligence-based analytics tools provide accurate and efficient management in agriculture.

However, there are also some problems in the digitalization process. In particular, the insufficient level of digital literacy of farmers, the high cost of technologies, infrastructure limitations in rural areas, and the lack of specialists are hindering the widespread implementation of Smart Agriculture technologies. To solve these problems, it is necessary to strengthen cooperation between the state, scientific organizations, and the private sector.

In the future, for the development of digital agriculture in Uzbekistan, it is important to expand farmer training programs, provide financial support for innovative technologies, develop local agrotechnology production, and improve digital infrastructure in rural areas.

In conclusion, Smart Agriculture technologies are a future development model for Uzbek agriculture, which not only increase economic efficiency, but also serve to ensure food security, environmental sustainability, and international competitiveness.

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ARTIFICIAL INTELLIGENCE IN BUSINESS MANAGEMENT: OPPORTUNITIES AND CHALLENGES FOR UZBEKISTAN

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Abstract. *Artificial Intelligence (AI) is considered to be one of the most progressive technologies that can be implemented in business management today. By employing AI technologies, companies can achieve higher rates of operational efficiency and strategic decision-making, reduce costs, and increase the overall level of services provided to clients. At the same time, the process of integrating technology into business operations can be complicated by various factors depending on the country in which it is being implemented. Uzbekistan has made great strides in recent years in terms of digitizing the economy and developing new government services and innovative technologies. Nevertheless, the use of AI technologies in business management is still underdeveloped and has its barriers and challenges that need to be taken into account.*

The purpose of this study is to comprehensively assess the opportunities and existing barriers to the use of artificial intelligence in business management in Uzbekistan. The study used a systematic literature review, comparative analysis, statistical data study, and conceptual approaches. The results show that the gradual introduction of AI technologies significantly increases the competitiveness, quality of management and innovative potential of enterprises. At the same time, improving

public policy, developing digital infrastructure and increasing investment in human capital are considered the main conditions for AI transformation.

Keywords: *Artificial Intelligence, Business Management, Digital Transformation, Innovation, Uzbekistan, AI Adoption, Corporate Performance.*

Annotatsiya. *Sun'iy intellekt (SI) bugungi kunda biznes boshqaruvida qo'llanilayotgan eng istiqbolli texnologiyalardan biri hisoblanadi. Sun'iy intellekt texnologiyalarini joriy etish korxonalarga operatsion samaradorlikni oshirish, strategik qarorlar qabul qilish sifatini yaxshilash, xarajatlarni kamaytirish hamda mijozlarga ko'rsatilayotgan xizmatlar sifatini oshirish imkonini beradi. Shu bilan birga, ushbu texnologiyalarni biznes jarayonlariga integratsiya qilish mamlakatning iqtisodiy va institutsional sharoitlariga bog'liq holda turli to'siq va muammolar bilan kechishi mumkin. So'nggi yillarda O'zbekiston iqtisodiyotni raqamlashtirish, elektron davlat xizmatlarini rivojlantirish va innovatsion texnologiyalarni joriy etish borasida sezilarli yutuqlarga erishdi. Biroq biznes boshqaruvida sun'iy intellekt texnologiyalaridan foydalanish hali yetarli darajada rivojlanmagan bo'lib, uni keng joriy etishga to'sqinlik qilayotgan qator omillar mavjud.*

Mazkur tadqiqotning maqsadi O'zbekistonda biznes boshqaruvida sun'iy intellektdan foydalanishning imkoniyatlari va mavjud to'siqlarini kompleks baholashdan iborat. Tadqiqotda tizimli adabiyotlar tahlili, qiyosiy tahlil, statistik ma'lumotlarni o'rganish hamda konseptual tahlil usullaridan foydalanildi. Tadqiqot natijalari sun'iy intellekt texnologiyalarini bosqichma-bosqich joriy etish korxonalarning raqobatbardoshligini oshirish, boshqaruv sifatini yaxshilash va innovatsion salohiyatini kuchaytirishga xizmat qilishini ko'rsatdi. Shu bilan birga, davlat siyosatini takomillashtirish, raqamli infratuzilmani rivojlantirish hamda inson kapitaliga investitsiyalarni ko'paytirish sun'iy intellekt asosidagi transformatsiyaning muhim shartlari sifatida e'tirof etildi.

Kalit so'zlar: *sun'iy intellekt, biznes boshqaruvi, raqamli transformatsiya, innovatsiyalar, O'zbekiston, sun'iy intellektni joriy etish, korxona faoliyati samaradorligi.*

Аннотация. *Искусственный интеллект (ИИ) считается одной из наиболее перспективных технологий, применяемых в современном управлении бизнесом. Использование технологий ИИ позволяет компаниям повысить операционную эффективность, улучшить качество стратегического принятия решений, сократить издержки и повысить общий уровень предоставляемых услуг. Вместе с тем процесс интеграции ИИ в бизнес-процессы может сопровождаться различными трудностями, обусловленными особенностями экономической и институциональной среды конкретной страны. В последние годы Узбекистан достиг значительных успехов в цифровизации экономики, развитии электронных государственных услуг и внедрении инновационных технологий. Однако применение технологий искусственного интеллекта в управлении бизнесом остается недостаточно развитым и сталкивается с рядом барьеров и вызовов, требующих дальнейшего изучения.*

Целью данного исследования является комплексная оценка возможностей и существующих барьеров внедрения искусственного интеллекта в управление

бизнесом в Узбекистане. В исследовании использованы методы систематического обзора литературы, сравнительного анализа, анализа статистических данных и концептуального анализа. Полученные результаты показывают, что поэтапное внедрение технологий искусственного интеллекта способствует повышению конкурентоспособности предприятий, улучшению качества управления и усилению их инновационного потенциала. В то же время совершенствование государственной политики, развитие цифровой инфраструктуры и увеличение инвестиций в человеческий капитал рассматриваются как ключевые условия успешной цифровой трансформации на основе искусственного интеллекта.

Ключевые слова: *искусственный интеллект, управление бизнесом, цифровая трансформация, инновации, Узбекистан, внедрение искусственного интеллекта, эффективность деятельности предприятий.*

INTRODUCTION

The development of artificial intelligence in the global economy is fundamentally changing the way businesses are managed. AI algorithms allow for the rapid processing of large amounts of data, forecasting market trends, analyzing customer behavior, and optimizing strategic decisions. Therefore, AI is becoming an integral part not only of the information technology sector, but also of economics, logistics, finance, marketing, and human resource management. Recent scientific research has recognized AI as an important factor in increasing the productivity, innovative potential, and global competitiveness of enterprises.

In Uzbekistan, within the framework of the "Digital Uzbekistan - 2030" strategy, special attention is paid to the digitization of economic sectors, the automation of business processes, and the introduction of modern management technologies. Initial initiatives are being observed to develop artificial intelligence-based management systems, especially in the agricultural sector, logistics, and service sectors. As Asamov (2025) noted, the introduction of digital transformation and AI technologies will increase the accuracy of management decisions and significantly improve the efficiency of resource use.

However, there are challenges in implementing AI technologies in business management, such as data quality, cybersecurity, lack of qualified specialists, and the level of development of the regulatory framework. This study aims to scientifically assess these opportunities and challenges in the conditions of Uzbekistan.

LITERATURE REVIEW

Research on artificial intelligence and business management has grown dramatically over the past five years. Bibliometric analyzes show that AI has become one of the areas most associated with strategic management, business process optimization, decision support, and sustainable development in management sciences. Dumas and co-authors (2022) state that AI-Augmented Business Process Management Systems (AI-Augmented Business Process Management Systems) will create a flexible, predictive and explainable management model for organizations. According to them, AI will not replace human decisions, but will support them with scientific data.

Asamov (2025) notes that the use of digital transformation, IoT, Big Data and AI technologies in the agricultural management of Uzbekistan will increase the efficiency of resource use, reduce logistics costs and strengthen food safety. These conclusions are also relevant for business management and confirm the strategic role of artificial intelligence in corporate management.

Other studies point to technological infrastructure, an open data ecosystem, digital literacy and management culture as key factors for the successful implementation of AI. Therefore, the implementation of AI in developing economies is not only a technical issue, but also closely related to institutional and governance reforms.

METHODS

This study aims to comprehensively assess the impact of artificial intelligence (AI) technologies on business management in Uzbek enterprises. The research methodology was developed based on a mixed-method approach. This approach, by combining qualitative and quantitative analysis methods, allows for a deeper analysis of the impact of AI technologies on enterprise efficiency, management quality, and competitiveness.

The theoretical basis of the study is digital transformation, innovative management, Dynamic Capabilities Theory, Technology Acceptance Model (TAM), and Resource-Based View (RBV). These theories interpret artificial intelligence not as a simple information technology, but as a strategic resource of the enterprise. Modern research shows that the role of AI technologies in digital transformation is to increase production efficiency, reduce costs, and improve the accuracy of management decisions. Asamov (2025) also emphasizes that digital technologies and AI are an important factor in increasing the efficiency of management in the conditions of Uzbekistan.

The study was carried out in three stages. At the first stage, scientific literature on artificial intelligence and business management in the Scopus, Web of Science, ResearchGate, ScienceDirect and Google Scholar databases was systematically studied. When selecting literature, priority was given to scientific articles published in 2020–2026 in the areas of AI, Business Management, Digital Transformation, Decision Support Systems, Industry 4.0 and Smart Business. In addition, state programs of Uzbekistan on the digital economy, reports of international organizations and Asamov's scientific works on digital transformation and management were separately analyzed.

At the second stage, a conceptual model was developed. The level of implementation of AI technologies was taken as an independent variable in the model. It was assessed through the following components:

a) management efficiency;
b) operating costs;
c) decision-making speed;
d) customer satisfaction;
e) innovative activity;

f) enterprise competitiveness.

The control variables were selected as enterprise size, industry, number of employees, level of digitization, and management experience.

The following scientific hypotheses were developed in the study:

H1. The introduction of artificial intelligence technologies will positively increase the efficiency of enterprise management.

H2. Analytical systems based on AI will significantly improve the quality of strategic decisions.

H3. The use of AI technologies will reduce operating costs and increase labor productivity.

H4. The main obstacles to the introduction of AI technologies in Uzbekistan are related to digital infrastructure, qualified personnel, and data quality.

These hypotheses are evaluated through statistical and logical analysis in the following results section.

The database was formed from several sources. International data were obtained from reports of the World Bank, OECD, McKinsey Global Institute, Stanford AI Index, and PwC. Data on Uzbekistan were enriched with official statistical publications, digitization programs, and scientific articles. This approach made it possible to compare the experience of Uzbekistan with global trends in AI technologies. Asamov's work on the economic efficiency and impact of digital transformation on logistics processes was also used as a methodological basis.

Descriptive statistics, comparative analysis, content analysis, and SWOT analysis were used in the analysis process. Descriptive statistics were used to summarize the trends in the use of AI technologies in business. Comparative analysis compared the experience of Uzbekistan with the practice of developed countries. Content analysis was used to systematize the content of scientific articles, government strategies, and international reports. SWOT analysis was used to identify the strengths and weaknesses, opportunities, and threats of AI technologies.

To ensure the reliability of the study, the principle of data triangulation was used. That is, one conclusion was checked through at least three different sources: international scientific articles, official statistical data, and scientific research on Uzbekistan. Such an approach increases the objectivity of the results and reduces excessive dependence on one source.

The study also used the following criteria to assess the cost-effectiveness of AI technologies:

a) reduction of management costs;
b) reduction of decision-making time;
c) degree of automation of business processes;
d) quality of customer service;
e) change in profit and productivity indicators;
f) share of innovative products and services.

These indicators allow for a multi-criteria assessment of the impact of AI technologies on enterprise performance.

One of the important aspects of the methodology is to take into account the specific institutional conditions of the Uzbek economy. The introduction of AI technologies in developing economies is not only a technological issue, but is also closely related to the investment climate, public policy, human capital and digital infrastructure. Therefore, the research results cover economic and institutional factors, along with technical factors. This approach is consistent with the concept of digital transformation and sustainable management put forward by Asamov.

RESULTS

Current Level of Artificial Intelligence Adoption in Business Management. The penetration of artificial intelligence technologies into the business environment of Uzbekistan has been accelerating significantly in recent years. In particular, the scope of use of AI-based solutions is expanding in the banking and finance, telecommunications, e-commerce and logistics sectors. Artificial intelligence is being used in enterprises in processes such as customer service, demand forecasting, warehouse logistics management, and financial risk assessment.

Asamov (2025) emphasizes the increasing importance of AI and big data technologies in improving the efficiency of digital transformation management. International studies also show that enterprises that implement AI technologies make faster decisions, reduce operating costs, and increase innovative potential.

Digital and Artificial Intelligence Readiness of Uzbekistan. The level of implementation of artificial intelligence technologies in business management is closely related to the overall digital readiness of the country. The results of the study show that the development of digital infrastructure in Uzbekistan in recent years is creating an important basis for the use of AI technologies.

According to the World Bank's World Development Indicators, the share of Internet users in Uzbekistan reached 90 percent of the population in 2024. This indicator represents a significant increase compared to the low levels in the early 2010s and indicates the formation of a broad digital coverage necessary for the digitization of business processes.

Table-1. Digital infrastructure indicators of Uzbekistan (2020–2024).

Indicator	2020	2021	2022	2023	2024
Internet users (% of population)	~71%	~76%	~83%	89%	90%
Digital government development	Increasing	Increasing	Increasing	Increasing	Advanced
Digital business environment	Developing	Developing	Growing	Growing	Expanding

The results of the table show that Uzbekistan is forming the basic digital conditions for the adoption of AI technologies. High internet coverage expands the opportunities for enterprises to use cloud services, e-commerce platforms, digital management systems and AI-based services.

At the same time, the presence of internet infrastructure is not a sufficient factor for AI transformation. The effective use of AI systems requires a high-quality database,

computing power and qualified specialists. Therefore, Uzbekistan's AI readiness should be assessed not only by technological connectivity, but also by human capital and an innovative ecosystem.

Figure-1. Internet penetration as a foundation for AI adoption in Uzbekistan (2015–2024).

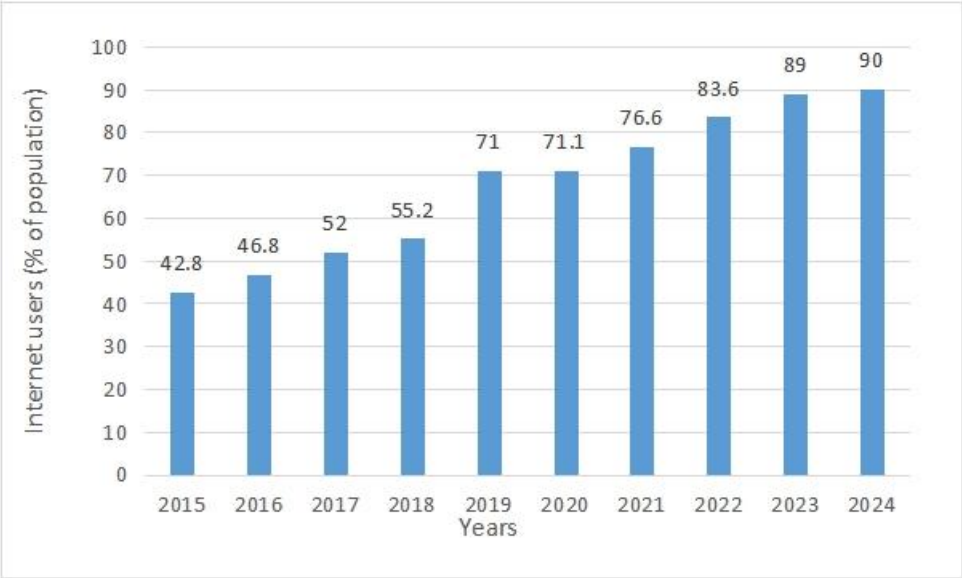


Figure 2 demonstrates the rapid expansion of digital connectivity in Uzbekistan between 2015 and 2024. Internet penetration increased from 42.8% in 2015 to approximately 90% in 2024, creating an essential technological foundation for artificial intelligence adoption in business management. The continuous growth of digital access indicates improved readiness of enterprises and consumers to utilize AI-based services, cloud platforms, and data-driven decision-making systems.

Global Artificial Intelligence Adoption and Business Impact. To understand the development of AI in the Uzbek business sector, it is important to compare it with global trends. According to the AI Index 2025 report published by Stanford University Human-Centered Artificial Intelligence, 78% of organizations reported using AI technologies in at least one business process in 2024. This figure has increased from 55% in 2023.

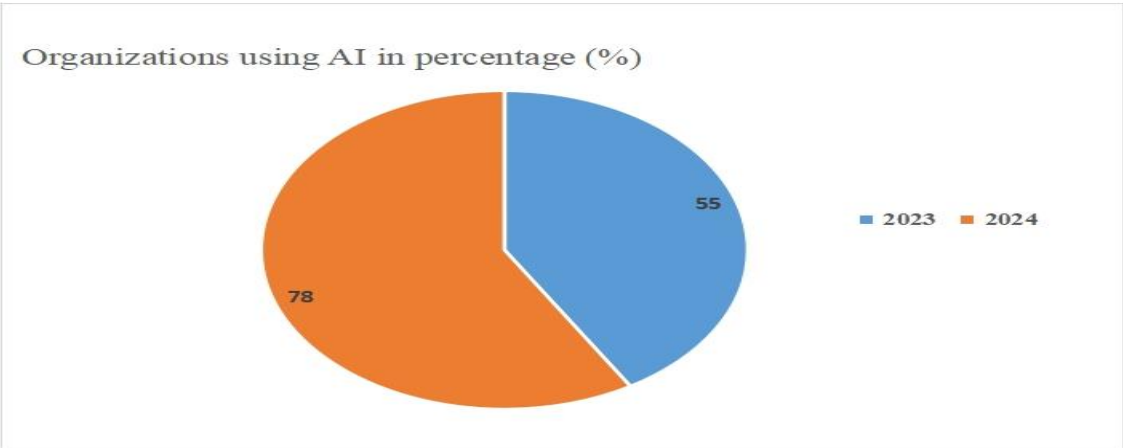


Figure-2. Global AI adoption in organizations between 2023 and 2024.

The results show that AI is moving from an experimental technology to a key strategic tool in business management. AI solutions are especially widely used in marketing, customer service, manufacturing, logistics, and financial analysis.

According to the Stanford AI Index, private AI investments in the United States will reach $109.1 billion in 2024, while global investments in generative AI have increased dramatically. This indicates that AI technologies will play a key role in future business models and management systems.

Artificial Intelligence Adoption Opportunities and Barriers in Uzbekistan's Private Sector. The integration of artificial intelligence technologies into business management is one of the new strategic directions in the digital transformation of the Uzbek economy. The results of the study show that, although the country has made significant progress in digital services, e-government, financial technologies and business process automation, the widespread use of AI technologies in the private sector is still at the development stage.

The report on the introduction of artificial intelligence in the private sector of Uzbekistan, prepared by the United Nations Development Programme, identifies financial capabilities, technological infrastructure, human capital and the regulatory environment as the main factors influencing the adoption of AI technologies. The report analyzes the existing constraints in the implementation of AI solutions, especially for micro, small and medium-sized enterprises.

Table-2. Main barriers affecting AI adoption in Uzbekistan's private sector.

Barrier factor	Impact level	Explanation
Lack of AI-skilled specialists	High	Limited availability of professionals in AI, machine learning and data analytics
High implementation costs	High	Initial investment required for software, infrastructure and training
Limited access to quality data	Medium–High	Many companies lack structured digital databases
Insufficient digital infrastructure	Medium	Advanced AI solutions require stronger computing capacity
Regulatory uncertainty	Medium	Businesses need clearer AI governance frameworks
Organizational resistance	Medium	Employees may hesitate to adopt AI-based workflows

The results of the table show that the biggest constraint to the development of AI in Uzbekistan is not the technology itself, but the human capital that effectively manages it. Modern AI systems do not work effectively by purchasing software alone; they require specialists with the ability to manage data, understand algorithms, and integrate them into business processes.

This result is also consistent with international experience. According to the Stanford AI Index 2025 report, the use of AI in companies around the world has increased dramatically, with 78% of organizations reporting that they are using AI technologies in at least one business process in 2024. At the same time, it is noted that to get real economic benefits from AI, it is not only necessary to have the technology, but also to properly integrate it into the business strategy.

AI Opportunities for Business Management Transformation in Uzbekistan. The results of the study identified several key opportunities for AI technologies for Uzbek business management.

The first opportunity is to improve the quality of decision-making. AI-based analytical systems allow managers to make more accurate and faster decisions by processing large amounts of data. For example, AI is becoming increasingly important in processes such as credit risk assessment in the banking sector, demand forecasting in the trade sector, and route optimization in the logistics sector.

The second opportunity is to increase operational efficiency. Automated systems reduce repetitive tasks and help employees focus on high-value activities. Global studies have shown that AI helps reduce costs, especially in service delivery, supply chain management, and software development processes.

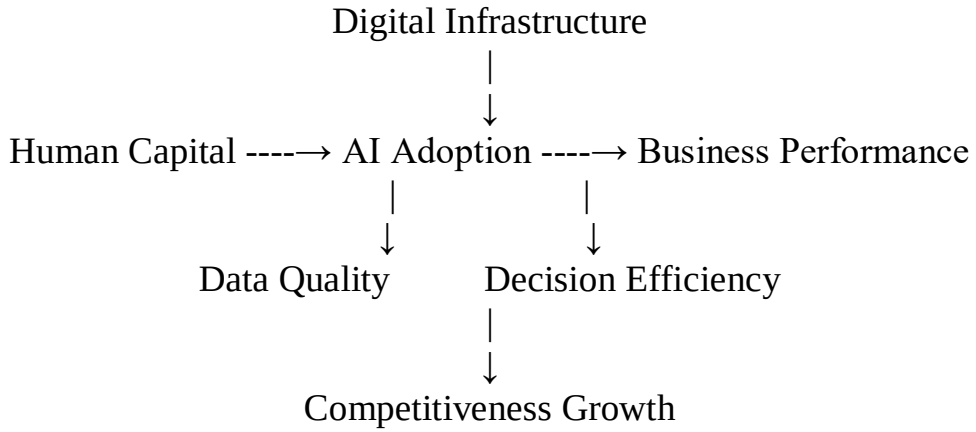
The third opportunity is to create innovative business models. Generative AI, chatbots, intelligent recommendation systems, and forecasting platforms are enabling businesses to provide personalized services to customers.

Table-3. Potential areas of AI application in Uzbekistan business sectors.

Sector	AI application	Expected business effect
Banking	Fraud detection, credit scoring	Reduced financial risks
Logistics	Route optimization, demand forecasting	Lower transportation costs
Agriculture	Smart farming, yield prediction	Higher productivity
Retail	Recommendation systems, chatbots	Improved customer experience
Manufacturing	Predictive maintenance	Reduced downtime
Healthcare	Diagnostic assistance	Improved service quality

The table below identifies the key areas of AI applications in major economic sectors of Uzbekistan and provides a brief overview of the potential impacts on intensification, risk reduction, productivity, and service quality. The data source includes international research on AI, UNDP Uzbekistan's analysis of the AI impact on various fields, and academic literature regarding digital transformation.

Figure-3. Relationship between AI adoption factors and business performance. Conceptual model



The results of this model show that AI technologies do not directly affect business performance, but rather through several intermediary factors. That is, if an enterprise does not have a strong digital infrastructure, quality data, and qualified specialists, it will be difficult to achieve the expected results from AI technologies.

SUMMARY OF RESULTS

The overall results show that Uzbekistan has important initial conditions for introducing AI technologies into business management. Increased Internet coverage, the development of digital public services, and innovative policies are contributing to the formation of an AI ecosystem.

However, compared to international experience, the main task for Uzbekistan is not simply to import AI technologies, but to adapt them to local business needs. This requires strengthening cooperation between universities, research centers, and the business sector, expanding AI educational programs, and creating financial support mechanisms for enterprises.

Based on the results, the following main conclusions were drawn:

1. AI technologies are a strategic tool that increases the efficiency of business management.
2. A digital base is being formed for the development of AI in Uzbekistan.
3. Human capital and data quality are key factors for the success of AI.
4. Public-private partnerships are crucial in developing an AI ecosystem.

DISCUSSION

The results of this study showed that artificial intelligence (AI) technologies are becoming an important strategic factor in increasing the efficiency of business management, improving strategic decisions and strengthening the competitiveness of enterprises. Although the development of AI technologies in Uzbekistan is still at an early stage, digital transformation processes, state policy and the need for technological innovation in the private sector are creating the basis for the rapid development of this area.

The results of the study show that the use of AI technologies allows enterprises to accelerate the process of making management decisions, analyze large amounts of data and automate business processes. These results are consistent with international research and show that artificial intelligence is becoming a strategic management resource in business organizations, not just a simple automation tool. Studies conducted by the McKinsey Global Institute also noted that generative AI and analytical systems can increase the productivity of organizations, reduce costs and expand the possibilities of creating new value.

One of the greatest opportunities for AI technologies for Uzbekistan is to increase efficiency in existing economic sectors. AI-based systems have great potential, especially in the fields of banking and finance, logistics, agriculture, manufacturing and services. Asamov's research on digital transformation and agrarian management also emphasizes that the use of modern digital technologies, including big data, automation and intelligent systems, allows for the efficient use of resources and improved management quality (Asamov, 2025). These ideas are consistent with the

results of this study, since AI is not only a technological innovation, but also a management mechanism that increases economic efficiency.

At the same time, the results of the study also showed the existing problems in the widespread introduction of AI technologies. One of the main problems is the lack of qualified human capital. Highly qualified specialists in data analysis, programming, machine learning and digital management are required to develop and manage artificial intelligence systems. This problem has been noted in many studies in developing countries. According to the Organization for Economic Co-operation and Development (OECD), the successful implementation of AI technologies depends not only on technological infrastructure, but also on human capital and institutional readiness.

In addition, the insufficient development of data management systems in the business sector of Uzbekistan is one of the factors affecting the effective functioning of AI technologies. Artificial intelligence algorithms require high-quality, systematic and large-scale data. If data collection, storage and processing systems are not developed in enterprises, the effectiveness of AI solutions will decrease. Therefore, Data Governance, cybersecurity and the development of digital infrastructure in enterprises should be an important part of the AI strategy.

The results of the study also show the role of public policy in the development of AI. Strategic initiatives are being implemented in Uzbekistan to develop the digital economy, improve the e-government system and develop artificial intelligence technologies. These policy directions have a positive impact on the technological renewal of the business sector. However, the formation of an AI ecosystem requires further strengthening of cooperation between the state, universities and the private sector.

The results of this study can also be compared with the experience of other developing countries. For example, countries such as South Korea, Singapore and the United Arab Emirates have made the development of AI a central direction of their national innovation strategy. The experience of these countries shows that to obtain economic efficiency from AI technologies, it is not enough to purchase technology alone; it is necessary to jointly develop the education system, scientific research, startup ecosystem and business environment.

Overall, this study shows that AI technologies have great potential for business management in Uzbekistan. However, to fully exploit these opportunities, it is necessary to develop technological infrastructure, improve digital skills, improve data management systems and form an innovative management culture. Thus, artificial intelligence should be considered not only as a means of increasing efficiency for Uzbek enterprises, but also as a strategic factor ensuring long-term economic development and global competitiveness.

CONCLUSION

This study was aimed at analyzing the potential of artificial intelligence (AI) technologies in business management and the problems of their implementation in Uzbekistan. The results of the study showed that AI technologies have great potential for increasing management efficiency in enterprises, improving strategic decisions,

reducing operating costs, and accelerating innovative development. In particular, data-driven management, forecasting systems, automated services, and intelligent analytical platforms are helping to bring business processes to a qualitatively new level.

At the same time, the lack of qualified personnel, the level of development of digital infrastructure, data quality, and institutional problems are the main obstacles to the widespread introduction of AI technologies in Uzbekistan. To overcome these problems, it is necessary to strengthen cooperation between the state, higher education institutions, and the private sector, train AI specialists, and create an innovative environment for business.

In general, artificial intelligence is not only a technological innovation for the Uzbek business sector, but also a strategic tool that increases economic growth, management efficiency, and international competitiveness. In the future, an integrated approach to the development of AI technologies can significantly accelerate the country's transition to a digital economy.

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