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Innovative technology and technical means for the cultivation of row crops in the southern region of Kazakhstan

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ABSTRACT

Studies were conducted to adapt an innovative technology for cultivating row crops using plastic mulch film under irrigated conditions in the southern region of Kazakhstan. The effects of different types of mulch films on soil temperature and moisture regimes, as well as on agrophysical soil properties and crop yield, were investigated. A technological machinery system was developed to facilitate the implementation of this technology in agricultural production. Soil mulching with plastic film is an effective agronomic practice that enables integrated regulation of soil moisture, temperature, and nutrient regimes. Various types of polyethylene films were used for soil mulching. The results of the study on temperature and moisture regimes under black and transparent films demonstrated that all tested films contributed to soil warming, moisture conservation through reduced evaporation, and maintenance of loose soil structure. The main advantage of black film is its ability to suppress weed growth. Elevated temperatures under the mulch film, prevention of soil desiccation, and optimal soil density promoted earlier seedling emergence by 3-4 days and accelerated the onset of the fruiting stage by 12-14 days compared to the control. Crop yields under film mulching increased by 1.6-1.8 times relative to open-field conditions. Increasing film width from 40 cm to 90 cm resulted in yield increases of 35% for cucumbers and 25% for tomatoes. When using 180 cm wide film, melons were sown with row spacing of 360 cm and intra-row spacing of 60 cm; their yield increased by 109% compared to open-field cultivation. Reduced soil surface evaporation allowed a decrease in the number of irrigations: for cucumbers and tomatoes, from seven under open-field conditions to five when using 40 cm film and to four when using 90 cm film. For melons, irrigation frequency decreased from five to four under film mulching. For large-scale implementation of this technology in irrigated areas of southern Kazakhstan, a technological machinery system was developed, including a vertical rotary cultivator for shallow soil milling (VRC-2.8) prior to film laying, and a combined seeding unit (CSU-2) for drip tape placement, film laying, and simultaneous seed sowing under drip irrigation. Performance analysis showed that these machines ensured optimal conditions for the growth and development of sugar beet and soybean. The application of the developed machinery system increased yields of sugar beet and soybean by 73% and 36%, respectively, and reduced seasonal irrigation water requirements by 36% and 61%. Thus, the application of mulch film technology combined with the developed machinery system is highly relevant and promising for irrigated agriculture.

Keywords: Innovative technology, Machinery system, Mulch film, Soil milling, Rotary cultivator, Combined seeding unit, Row crops.

INTRODUCTION

Water supply in Kazakhstan largely depends on transboundary rivers originating from China, Russia, Uzbekistan, and Kyrgyzstan, which account for approximately 44% of total surface water inflow. This inflow is rapidly

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decreasing due to accelerated economic and social development in neighboring countries. By 2050, the projected water deficit in Kazakhstan may reach 20 billion m³, or approximately 70% of national water demand, and is expected to increase further if no substantial measures are taken (Balgabaev *et al.* 2016; Bukharov *et al.* 2016). To address this issue, it is proposed to reduce water consumption in agriculture by 6.5-7.0 billion m³ by 2030. One of the key measures is the implementation of modern drip irrigation systems and other water-saving technologies, which can reduce irrigation water use by approximately 1.5 billion m³ (Kazakhstan 2024).

In this context, the development of technologies for cultivating row crops (vegetables, melons, sugar beet, soybean, etc.) using mulch film in combination with drip irrigation is highly relevant. Such technologies contribute to reduced irrigation water consumption by minimizing evaporation losses from the soil surface, which can account for up to 60-70% of soil moisture reserves. Additionally, they help prevent soil erosion by reducing irrigation runoff and suppress weed growth. The creation of favorable temperature and moisture conditions under mulch film also enhances crop productivity (Shaikh *et al.* 2023).

Various materials are used for soil mulching, including polyethylene films (Kagan & Popova 1970). According to both international and domestic studies, film mulching is a promising agronomic practice that allows integrated control of soil water, temperature, and nutrient regimes. Furthermore, this practice reduces labor costs associated with weeding, decreases field weed infestation, and lowers the application rates of herbicides, which are among the most environmentally hazardous inputs (Soromotina & Fedurina 2012; Shiukhy *et al.* 2015; Latypova & Soromotina 2016; Ovchinnikov *et al.* 2017).

However, the adoption of this technology is constrained by the lack of appropriate machinery and insufficient scientific and technological justification for its application. This necessitates the development of specialized technical equipment for its effective implementation.

Therefore, the aim of this study was to identify optimal soil mulching methods, as well as to develop a corresponding cultivation technology and technical means for its implementation.

In accordance with this objective, the study investigated the effects of film properties (transparent and black), mulch strip width, and sowing patterns on soil temperature and moisture regimes, as well as on the yield of row crops.

MATERIALS AND METHODS

Field and laboratory experiments were conducted at the fields of the Kazakh Research Institute of Agriculture and Crop Production, located in the irrigated south-eastern region of Kazakhstan, on light chestnut soils with a medium loam texture.

The laboratory experiments investigated the effects of different types of mulch film (transparent and black opaque) and the width of the mulched strip on soil temperature and moisture regimes, as well as on crop yield. Polyethylene film with strip widths (S) of 40, 70, and 90 cm was laid on the soil surface using a laboratory film-laying unit developed on the basis of the MRC-4.2 (mounted row cultivator). The structural and technological scheme of the unit section is shown in Fig. 1.

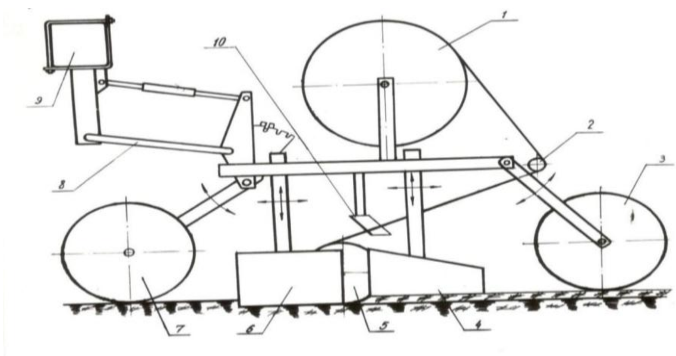

Fig. 1. Structural and technological scheme of the film-laying unit section; 1 – film roll; 2 – guide; 3 – pressing device; 4 – covering discs; 5 – press roller; 6 – soil deflector; 7 – support wheel; 8 – section suspension; 9 – frame; 10 – blades.

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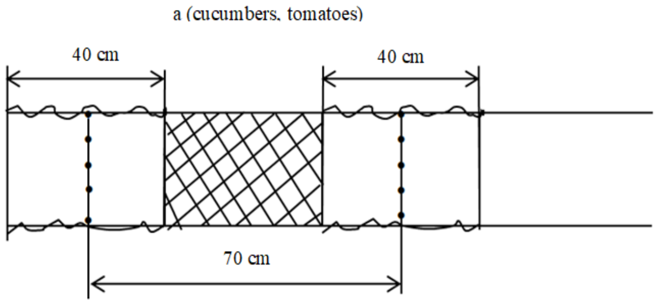
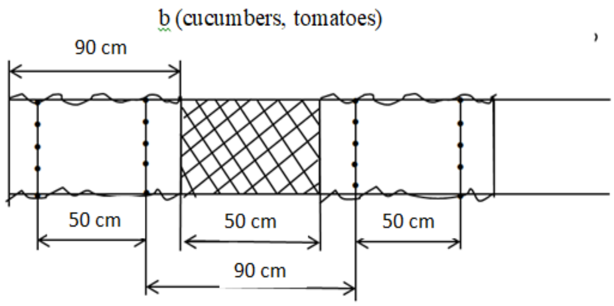
During operation, the soil deflector (6) removes the upper soil layer, levels the surface, and shifts soil toward the future inter-row spaces, forming soil ridges. The polyethylene film, fed from the roll (1) through the guide (2), is laid onto the leveled surface using the press roller (5). The laid film is then covered with soil from the ridges by means of the covering discs (4).

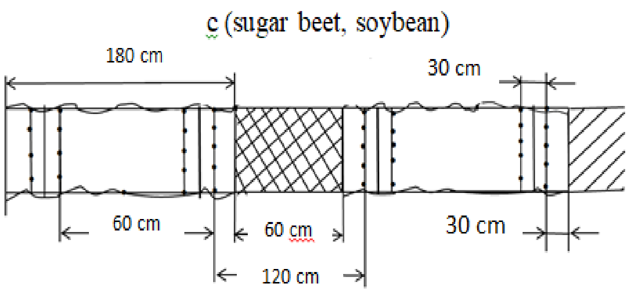
Film perforation and the formation of planting holes were performed manually, with a spacing of 20 cm between holes. The layout of mulch film placement and crop sowing in field experiments is shown in Fig. 2.



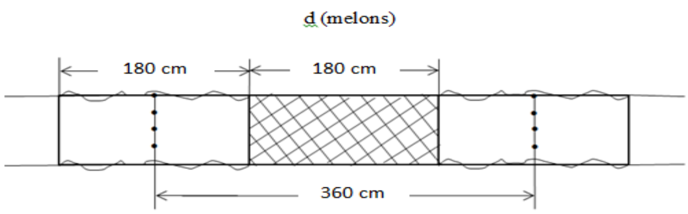
Single-row planting.
Row spacing: 70 cm; Mulch film width: 40 cm;
Width of the open soil strip: 30 cm.



Double-row planting scheme 50 + 90 cm.
Mulch film width: 90 cm; Width of the open soil strip: 50 cm;
Distance between rows: 50 cm; Row spacing: 90 cm).



Double-row planting scheme 50 + 90 cm.
Mulch film width: 90 cm; Width of the open soil strip: 50 cm.



Single row planting scheme
Row spacing: 360 cm; Mulch film width: 180 cm; Width of the open soil strip: 180 cm.

Fig. 2. Layout of mulch film placement and crop sowing in field experiments.

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Under laboratory conditions: at a film width of 40 cm, single-row sowing of cucumbers was performed with a row spacing of 70 cm; at a film width of 90 cm, double-row sowing of cucumbers and tomatoes was applied (Fig. 2a, b). These sowing schemes are also applicable to vegetable crops such as eggplant, as well as to industrial crops such as soybean and sugar beet.
Following the positive results obtained regarding the effect of mulch film on crop yield, a technological machinery system was developed, including a vertical rotary cultivator (VRC-2.8) for high-quality pre-sowing soil milling, and a combined seeding unit (CSU-2). A field experiment was subsequently established for sugar beet and soybean cultivation using transparent film with a strip width of 180 cm. The sowing pattern was: 30×30+60+30×30+120 cm. The film covered a 60 cm inter-row space and four crop rows (two on each side). For soil aeration, an adjacent inter-row space of 60 cm was left uncovered (Fig. 2c). Pre-sowing soil loosening and leveling were carried out using the VRC-2.8 cultivator. Film laying, perforation, seed sowing, and drip tape placement between rows were performed simultaneously using a combined seeding unit developed by the Kazakh Research Institute of Agricultural Mechanization and Electrification in cooperation with the Kazakh Research Institute of Agriculture and Crop Production.
Watermelon and melon crops in the field experiment were sown in a single row on 180 cm wide film, with 60 cm spacing between planting holes (Fig. 2c).
Experimental conditions and soil agrophysical parameters were determined in accordance with GOST 20915-75 “Agricultural machinery. Methods for determining test conditions”; functional performance indicators of VRC and CSU in accordance with GOST 31345-2007 “Tractor seed drills. Test methods”; economic efficiency in accordance with GOST 23728-88 “Agricultural machinery. Basic principles and indicators of economic evaluation”.
Soil temperature and moisture were measured throughout the growing season using soil thermometers and moisture meters.

RESULTS AND DISCUSSION

Results of laboratory experiments

Since soil temperature and moisture regimes are the primary factors influencing crop yield, their dynamics were studied under black and transparent mulch films with widths of 40, 90, and 180 cm from April to September (Fig. 3).

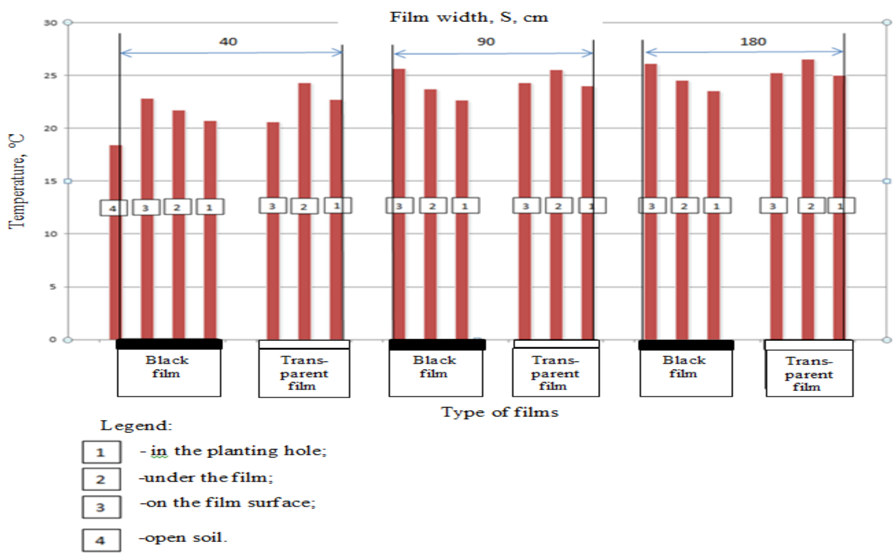

Fig. 3. Dynamics of average monthly temperature under black and transparent mulch films (April-September).

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The results showed that the temperature on the surface of the black film was higher due to its greater absorption and accumulation of solar energy compared to the transparent film.
At the same time, black opaque film acts as a thermal insulator. As a result, the soil temperature beneath it was lower by 1.2-1.8 °C, preventing overheating of the root system during sharp daytime temperature increases in the spring-summer period. In the perforation zone (planting holes), partial gas exchange led to a temperature decrease of 1.0-1.5 °C.
Transparent film allows solar radiation to pass through, resulting in lower surface temperature compared to black film. However, the soil beneath it warms more intensely, which may lead to plant overheating due to insufficient heat exchange with the atmosphere, especially when perforation is inadequate. The greatest risk occurs during the first few days after film installation. Over time, precipitation and wind-driven deposition of soil particles onto the film surface reduce its transparency and solar transmission.
Improper film laying and perforation, caused by insufficient soil leveling and the presence of large clods, may result in partial covering of planting holes. Under such conditions, at daytime temperatures of 25-27 °C, seedling damage or burning may occur. This effect was observed in our experiments where pre-sowing tillage was performed using implements with passive working elements (cultivators, harrows, etc.).
The main advantage of black opaque film identified in the experiments was complete suppression of weed vegetation beneath its surface. In addition, more stable diurnal temperature fluctuations under black film created favorable conditions for seed germination. Improved results were obtained by pressing and covering the edges of the film with soil and by partially mulching the surface of transparent film with soil, which reduced its transparency and prevented soil overheating.
For both black and transparent films, temperature at the surface, beneath the film, and in the perforation zone was lowest at 40 cm width and increased proportionally with increasing film width (90 and 180 cm), as shown in Fig. 3.
The study of soil moisture dynamics showed that mulch film reduced soil water evaporation by up to 80%, thereby increasing total soil moisture reserves, as confirmed by the data in Table 1. Since no significant differences were observed in moisture accumulation under films with widths of 90, 120, and 180 cm, Table 1 presents averaged values of total soil moisture content in the 0-50 cm soil layer.

Table 1. Average total soil moisture reserves in the 0-50 cm layer under film widths of 90, 120, and 180 cm.

Soil layer	Open soil	Black film	Transparent film
	Total moisture reserves (mm)	**Total moisture reserves (mm)**	**Total moisture reserve in the soil layers (mm)**
0-10	12.1	15.5	15.8
10-20	16.0	18.0	18.7
20-30	18.0	20.7	21.0
30-40	19.5	21.5	21.9
40-50	20.0	22.0	22.5
0-50	85.6	97.7	99.9

According to the obtained data, total soil moisture reserves in the 0-50 cm layer were higher by 14% under black film and by 16% under transparent film compared to open soil.
Narrow film (40 cm) demonstrated lower moisture retention capacity, with total moisture reserves in the 0-50 cm layer being lower than those observed under films with widths of 90 cm and 180 cm.
No significant differences in moisture accumulation were observed between black and transparent films.
Thus, the reduction of soil moisture evaporation under mulch film enables a decrease in irrigation water consumption during crop cultivation.
In addition to the temperature and water conditions, mulch film had a significant impact on agrophysical parameters, including the soil bulk density (Table 2).
The results indicate that under both black and transparent mulch films, the soil remained in a looser condition. Soil bulk density was lower by an average of 9.4% in May and 15% in July compared to open soil. Reduced soil density under mulch film provided optimal conditions for seed germination and root system development, which positively affected crop yield. No significant differences in soil density were observed between black and transparent films.

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Table 2. Soil bulk density under 90 cm mulch film (g cm^{-3})

Soil layer	Open soil		Black film		Transparent film	
	May 5	July 20	May 5	July 20	May 5	July 20
0-10	1.2	1.4	1.05	1.15	1.0	1.14
10-20	1.25	1.45	1.15	1.2	1.1	1.22
20-30	1.3	1.47	1.2	1.25	1.2	1.24
30-40	1.3	1.47	1.22	1.27	1.25	1.25
40-50	1.35	1.49	1.25	1.32	1.25	1.3

The combined effects of improved soil temperature and moisture regimes, along with enhanced agrophysical properties under mulch film, had a significant impact on crop yield, irrigation regime, and weed infestation (Table 3).

Table 3. Efficiency of row crop cultivation under mulch film.

Crop	Sowing method	Yield (centners ha^{-1})	Number of irrigations	Weed density, plants per linear meter
Cucumbers				
Sowing in the open soil		150	7	60
Sowing in the mulch film				
S = 40 cm	70 × 70			
-transparent		180	5	73
-black		195	5	2
S = 90 cm	50 × 90			
-transparent		243	4	65
-black		235	4	2
Tomatoes				
Sowing in the open soil		120	7	75
Sowing in the mulch film				
S = 40 cm	70 × 70			
-transparent		160	5	105
-black		165	5	3
S = 90 cm	50 × 90			
-transparent		200	4	53
-black		215	4	3
Melons				
Sowing in the open soil		165	5	90
Sowing in the mulch film	360 × 60			
-transparent		345	4	100
-black		325	4	4

Note: S – film width

It was established that elevated temperatures under mulch film, prevention of soil desiccation, and optimal soil density contributed to earlier seedling emergence (by 3-4 days) and accelerated transition to the fruiting stage by 12-14 days compared to the control.

According to the data presented in Table 3, crop yields under mulch film increased by 1.6-1.8 times compared to open-field conditions. The primary factor influencing yield was film width. Increasing film width from 40 cm to 90 cm resulted in yield increases of 35% for cucumbers and 25% for tomatoes.

Melons were sown on 180-cm wide film with row spacing of 360 cm and 60 cm spacing between planting holes. Their yield increased by 109% compared to open-field cultivation. Reduced evaporation from the soil surface allowed a decrease in irrigation frequency: from seven irrigations under open-field conditions to five with 40-cm film and four with 90-cm film. For melons, irrigation frequency decreased from five to four under mulch film.

Transparent film, due to favorable moisture, soil density, and light conditions beneath it, stimulated weed germination. As a result, weed infestation was significant, and in some cases led to film displacement. Therefore, when using transparent film, it is necessary to apply herbicides or partially cover the film surface with soil.

Under black film, due to the absence of light, weed growth was almost completely suppressed. In rare cases, weeds appeared only in perforation holes.

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Weed infestation did not significantly depend on film width. Thus, film widths of 90 cm and above were found to be the most effective. The primary advantage of black film over transparent film lies in weed suppression, enabling environmentally friendly crop production without herbicide application.
For the implementation of mulch film-based cultivation technology under drip irrigation, a technological machinery system was developed, consisting of a vertical rotary cultivator (VRC-2.8), and a combined seeding unit (CSU-2).
Justification for the development of the VRC-2.8 cultivator. In the south-eastern region of Kazakhstan, pre-sowing soil preparation is carried out between March 20 and April 25 due to recurring spring frosts. At the end of March, a sharp increase in air temperature leads to rapid drying of the topsoil. As a result, soil clods harden, reaching hardness values of 3 MPa or more, making them difficult to break down. Consequently, the soil aggregate composition after conventional tillage does not meet agronomic requirements for sowing. According to agrotechnical standards: soil aggregates ≤ 2 cm should constitute 70-80%, and aggregates >3 cm are not allowed. However, in practice, after standard pre-sowing operations, the content of aggregates larger than 3 cm reaches 30-40%.
The time gap between soil preparation and sowing leads to additional soil drying and delayed seedling emergence. In the absence of precipitation, this necessitates increased seeding rates, resulting in higher labor and economic costs.
Therefore, there is a need for machinery with active working elements capable of ensuring high-quality pre-sowing soil preparation in a minimal number of passes.
The VRC-2.8 cultivator is a tractor-mounted implement attached via a three-point linkage and consists of a frame supporting: subsoilers (loosening tines) operating up to 28 cm depth, a main gearbox, a rotor with blades performing soil milling up to 16 cm depth, a leveling board, a rod roller for additional leveling and compaction. The unit is compatible with 14 kN traction class tractors. Thus, the VRC-2.8 performs four operations in a single pass: deep soil loosening, surface layer milling, soil leveling, and soil compaction. Given the high requirements for soil preparation in mulch film technology, the use of such equipment is essential.
Justification for the development of the CSU-2. Numerous studies have been conducted on the development of machinery and technologies for soil mulching with film (ZM *et al.* 2018; Li *et al.* 2024; Bai *et al.* 2024; Sun *et al.* 2026).
Foreign manufacturers offer a wide range of machines for film laying and sowing, typically designed as combined units performing both operations. These machines generally: unwind film rolls, lay film on the soil surface, fix and cover film edges with soil, perforate the film at specified intervals, and sow seeds through the perforations.
However, these machines are not adapted to the soil and climatic conditions of Kazakhstan. They are highly specialized, designed for specific crops and planting schemes, and often do not include drip tape placement. Due to their high cost and limited seasonal utilization, they are not economically feasible for small farms.
Therefore, a combined seeding unit (CSU-2) was developed for drip tape placement, film laying, and seed sowing under drip irrigation. The CSU-2 unit can be recommended for crop cultivation in Southern Kazakhstan. It ensures high-quality execution of technological operations, preservation of soil fertility by reducing the number of machine passes, and reduced operational costs.
The key component of the CSU-2 ensuring high-quality sowing is the combined perforating-seeding working unit (Fig. 4), which consists of: a frame (1), an axle (2), a support wheel (3) equipped with nozzles (4) and valves (5), a coaxially mounted vacuum seed metering drum (6), connected via the axle to a fan system, including: a stationary housing (7), a seed hopper (8), a seeding disc (9) with holes (10), a seed stripper (11), a hole cleaner (12), and a discharge window (13) of length (l_1).
During operation of the seeding unit, the support wheel (3) interacts with the soil through the mulch film. It perforates the film and simultaneously forms a planting hole in the soil. At the same time, seeds from the hopper (8) are supplied into the housing (7) of the vacuum seed metering drum (6). The seeds adhere to the holes (10) of the rotating disc (9) and are transported toward the seed stripper (11) mounted on the drum housing. The seeds are then removed by the stripper (11) and roll along the inner surface of the drum toward the discharge window (13).
From the discharge window (13), with a length (l_1), the seeds fall directly into the nozzle (4) of the support wheel (3). The chord length of the nozzle cross-section ($l \geq l_1$) ensures reliable seed transfer into the nozzle. As the

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nozzle (4) exits the planting hole, its valve (5) opens, allowing the seed to be released into the hole, where it is simultaneously covered with soil.

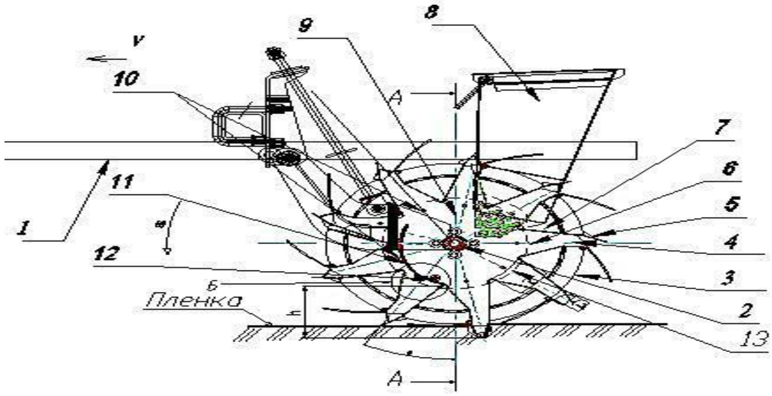
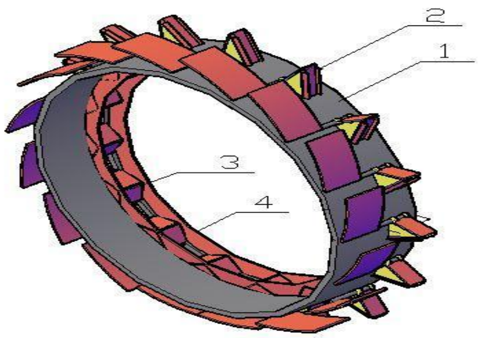


Fig. 4. Seed metering and perforation unit.

The rim (wheel) of the working unit is shown in Fig. 5.



1 – rim;
2 – perforating device (nozzle);
3 – distribution cone;
4 – side plates

Fig. 5. Rim (wheel) of the working unit.

The working units mounted on the frame of the seeding unit enable the following operations:

- pre-sowing soil preparation, mulch film laying, film perforation, seed sowing into planting holes, and soil covering of seeds.

During operation, a clod separator-leveler removes large soil aggregates from the surface. A front press roller following it compacts and levels the strip where drip irrigation tape is laid and mulch film is spread. The film edges are pressed and covered with soil. The combined perforating-seeding unit (Fig. 4) performs film perforation, forms planting holes, and sows seeds. Post-sowing press rollers press the film and cover the seeds with soil retained within the drum. The experimental prototype of the combined seeding unit is shown in Fig. 6.

Fig. 6. Experimental prototype of the combined seeding unit.

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3.2 The development of a technological machinery system, including the VRC-2.8 cultivator and the CSU-2 combined seeding unit, enabled the establishment of field experiments based on the proposed innovative technology

Field experiments were conducted at the fields of the Kazakh Research Institute of Agriculture and Crop Production on sugar beet and soybean crops. The soil of the experimental plot was light chestnut, and medium loam. The quality of pre-sowing soil preparation was assessed as satisfactory: soil moisture in the seed placement layer and soil bulk density were 15.7%, 0.99 g cm^{-3} respectively.

During the field experiments, operational performance of the experimental machinery prototypes for potential industrial implementation and productivity of sugar beet and soybean crops were evaluated.

Prior to the operation of the CSU-2 unit, pre-sowing soil milling was performed using the VRC-2.8 rotary cultivator. The VRC-2.8 cultivator in operation is shown in Fig. 7, and its brief technical characteristics in Table 4.

Fig. 7. Vertical rotary cultivator in operation.

Table 4. Technical characteristics and main requirements of the VRC cultivator.

Naming of parameters	Parameters
Working width (m)	2.8
Operating speed (km h^{-1})	up to 8
Soil loosening working elements:	
- for depths up to 28 cm	Subsoiler tine
- for depths up to 16 cm	Gear-driven vertical rotor with blades
Leveling unit	Leveling board
Roller type	Rod roller
Tractor compatibility	1.4 kN
Field capacity (per hour)	2.24

The quality of pre-sowing soil preparation achieved by the VRC-2.8 cultivator met agrotechnical requirements: soil moisture in the seed placement layer, soil bulk density, proportion of soil aggregates smaller than 20 mm, and surface roughness (ridge height): were 15.7%, 0.99 g cm^{-3}, 82.5%, ± 2.5 cm respectively.

On the prepared soil, the CSU-2 combined unit was used to simultaneously: lay mulch film, install drip irrigation tape, sow sugar beet and soybean seeds.

The CSU-2 in operation is shown in Fig. 8.

The sowing technology using the CSU-2 combined unit operates as follows. During forward movement of the unit, transparent mulch film with a width of 180 cm is laid according to a 60-60-60 cm scheme. Under this configuration, a 60 cm inter-row space and four crop rows (two on each side of the inter-row) with 30 cm spacing between rows are covered by the film. A 30 cm margin remains on each side of the film, ensuring proper embedding of the film edges into the soil. Adjacent inter-row spaces remain uncovered, allowing soil to be moved for covering the film edges and improving soil aeration beneath the mulch layer. Simultaneously, drip irrigation hoses are placed beneath the film between the crop rows.

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Fig. 8. Combined seeding unit in operation.

The sugar beet crops grown under mulch film with drip irrigation is shown in Fig. 9.

Fig. 9. Sugar beet crops grown under mulch film with drip irrigation.

The main performance indicators of the CSU-2 unit during sowing of sugar beet and soybean are presented in Table 5.

Table 5. Main performance indicators of the CSU-2 during sowing of sugar beet and soybean.

Parameter	**Value**			
	Control without film		**Treatment with film**	
1	**2**		**3**	**4**
Unit composition	**Tractor class 1.4 + CSU**			
Crop	**Sugar beet**	**Soybean**	**Sugar beet**	**Soybean**
Sowing pattern	**Four-row: 30 × 30 + 60 + 30 × 30 + 120**			
	Distance between perforation holes (cm)			
- set value	10.0	10.0	10.0	10.0
$\overline{X}$	10.2	10.4	9.8	10.3
±σ	1.8	1.6	1.2	1.07
γ (%)	17.6	15.4	12.2	10.4
	Number of seeds per hole			
- set value	1	1	1	1
$\overline{X}$	1.1	1.3	1.3	0.95
±σ	0.30	0.35	0.34	0.22
γ (%)	27.3	26.9	26.2	23.2
Seeding depth, cm				
- set value	4	4	4	4
$\overline{X}$	3.6	3.8	3.7	3.6
±σ			0.62	0.58
γ (%)			16.8	16.1
	Soil cover above seeds (cm)			
$\overline{X}$	1.8	2.2	1.1	0.9
±σ	0.3	0.25	0.2	0.15
γ (%)	16.7	11.4	18.2	16.7

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Analysis of the test results demonstrated that all functional performance indicators of the seeding unit were stable during operation.
The quality of mulch film laying is shown in Fig. 10.

Fig. 10. Quality of mulch film laying.

The data on yield and water regime of sugar beet and soybean are shown in Table 6.

Table 6. Yield and water regime of sugar beet and soybean.

No.	Treatment	Yield (centners ha^{-1})	Irrigation rate during growing season (m³ ha^{-1})
	Sugar beet		
1	Control (open soil)	305	6300
2	Mulch film	530	4600
	Soybean		
3	Control (open soil)	17.3	3200
4	Mulch film	23.7	1980

According to the obtained data, cultivation of sugar beet and soybean under mulch film using drip irrigation and the developed machinery system (VRC-2.8 cultivator and CSU-2 seeding unit) resulted in: an increase in yield by 73% for sugar beet and 36% for soybean, a reduction in seasonal irrigation water use by 36% and 61%, respectively.
Thus, the application of mulch film technology combined with the developed machinery system significantly increases crop productivity while reducing irrigation water consumption.

CONCLUSION

The results of the study of temperature and moisture regimes under black and transparent mulch films showed that both types contribute to soil warming, moisture conservation, and maintenance of a loose soil structure.
The primary advantage of black film is effective weed suppression. According to laboratory results, increased temperature under mulch film, prevention of soil desiccation, and optimal soil density contributed to earlier seedling emergence (by 3-4 days) and earlier transition to the fruiting stage (by 12-14 days) compared to the control.
Crop yields under mulch film increased by 1.6-1.8 times compared to open-field conditions. Increasing film width from 40 cm to 90 cm resulted in yield increases of 35% for cucumbers and 25% for tomatoes.
Melons grown on 180 cm wide film with row spacing of 360 cm and 60 cm spacing between planting holes showed a yield increase of 109% compared to open-field cultivation.
Reduced evaporation from the soil surface allowed a decrease in irrigation frequency: for cucumbers and tomatoes: from 7 (open soil) to 5 (40 cm film) and 4 (90 cm film), for melons: from 5 (control) to 4 under mulch film.

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A technological machinery system was developed for the cultivation of row crops using mulch film, consisting of the VRC-2.8 cultivator and the CSU-2 combined seeding unit. Field experiments confirmed that all technological operations performed by these machines met agrotechnical requirements.
The application of the developed machinery system for sugar beet and soybean cultivation under mulch film with drip irrigation increased yields by 73% and 36%, and reduced seasonal irrigation water requirements by 36% and 61% respectively.
Therefore, the implementation of mulch film technology using the developed machinery system in irrigated farming systems of Southern Kazakhstan will enhance crop productivity and significantly reduce irrigation water consumption.

Data Availability Statement

The entire data set that supports the results of this study will be published in the article itself.

Conflicts of interest

All the authors of the article confirm that there is no conflict of interest.

Author Statement

The author declares that all his co-workers are informed of this paper and its contents.
We confirm that neither the manuscript nor any parts of its content are currently under consideration or published in another journal.
All data obtained or analyzed in the course of this research are included in the article for publication.
Other or additional data that confirm the findings of this research are available upon request from the corresponding author.

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