Effectiveness of Sugar Beet Cultivation under Drop Irrigation in South-East Kazakhstan

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The article presents the results of field studies on the productivity and quality of sugar beet depending on drip irrigation techniques and modes, sowing technology, as well as mineral fertilizers application rates and timing. The article presents also conducted agro-economic assessment of sugar beet cultivation efficiency under drip irrigation on light chestnut soils of the Southeast of Kazakhstan.

Key words: Sugar beet, drip irrigation, light chestnut soil, mineral fertilizer, agro-economic assessment, sowing technology, weed infestation, productivity and assessment, irrigation mode.

The head of state N. Nazarbayev in his annual message to the people of Kazakhstan clearly outlined the tasks facing the agro-industrial complex, among which the priority task is to ensure food security of the country. At that, particular attention is paid to encouraging the production of basic foodstuffs, including sugar[1].

In the Republic of Kazakhstan (RK), sugar beet is the only cultivar which is used in the production of crystalline sugar and thus has a great economic importance in the fulfillment of the production program of the country.

Sown area of sugar beet during the years of its cultivation in the RK amounted to 80.8 thousand ha with an average yield of 270 kg/ha and more, while sugar production amounted to 180-190 thousand tons per year, accounting for just 20-25% of total demand.

The analysis of current situation with sugar beet production in the RK showed that the yield of this crop in recent years is at the level of 200-240 kg/ha that indicates extremely inadequate implementation of the potentiality of this valuable cultivar, the low level of its cultivation technology, and insufficient use of agrochemical and protective means. However, currently, the country has a real opportunity to revive the former glory of the sugar beet industry. The basis for this may be the availability of irrigated suburban resource potential, significant area of irrigated lands suitable for growing beets, abundance of warmth and especially sun light, a sufficient amount of labor force, and vast experience[2].

The government of the RK encourages the development of the sugar industry by subsidizing the villagers for the purchase of seeds, mineral fertilizers and chemical plant protection products that will enable in the coming years to

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increase the acreage of this crop up to 40 thousand hectares, increase the root crop up to 30-35 t/ha and double the production of white sugar.

This measure will enable to save more than 20 thousand jobs, improve the competitiveness of the sugar beet growing, and reduce in the proportion of sugar imports in the internal market[3].

Sugar beet is one of the main industrial crops, giving carbohydrate-rich root crops, which are used in production of sugar. Beet root crops contain 16-20% of sucrose. At high yield of beet root crops, the beet roots (40-50 t/ha) sugar production may reach up to 10 tons per hectare.

Factory processing of sugar beet roots gives by-products, namely beet pulp and molasses, which are of great economic importance. Dry substance of beets contains about 60% of molasses, about 15% of nitrogen-free extractive substances, and 8-9% of ash. Molasses is used for producing alcohol, food yeast, as well as lactic and citric acids. Sugar beet pulp (pressed beet chips) contains about 15% of dry solids, including 10% of nitrogen-free extractive substances, 3% of fibre, 0.7% of ash, 0.1% of fat, and 1.2% of crude protein.

Sugar beet pulp is a valuable feed for cattle. Thus, 100 kg of dry pulp contains 80 fodder units, while the same amount of sour and fresh pulp contains 10 and 8 fodder units, respectively. Waste sugar beet production - defecation mud is used as fertilizer. It contains 40-50% of lime, 15% of organic matter, 0.2-1.7% of nitrogen, 0.2-0.8% of phosphorus, and 0.5-0.9% of potassium.

Waste resulting from the harvesting of sugar beet (leaves, tops of heads, and tips of the roots), are used for animal feed in fresh, silage or dried form. A large part of waste are leaves, amounting for 35-50% of the roots mass; they contain up to 20% of dry basis, including 2.5-3.5% of protein, 0.8% of fat and vitamins. Moreover, 100 kg of the tops contains 18-20 fodder units. At root crops harvest of 30 t/ha, sugar beets along with tops (15 t/ha) give 10,500 fodder units per 1 ha.

The inclusion of sugar beet in crop rotation is of great agronomic importance as it contributes to improving the farming and yields of subsequent crops due to the deep tillage, the application of large rates of fertilizer, as well as weed control and pest management.

To provide population of the RK with sugar, we must produce annually not less than 500 thousand tons of crystal sugar. At the present time just 25-30 thousand tons of sugar is produced out of domestic raw materials that meets the needs of the population by just 5-7%. However, according to the food security requirements, the level of sugar production from domestic raw materials should be not less than 20%. In order to ensure food security in terms of this product, it is necessary to increase the cultivated area and implement modern technologies of sugar beet cultivation, as well as to use foreign practices in beets cultivation.

One of the main reasons constraining development of the beet growing industry in the RK is the lack of irrigation water required for existing technologies of sugar beet cultivation.

Water availability in the future will become a serious limiting factor in the development of the country's economy. This is caused by the growing shortage of water resources, associated with their interstate distribution, rigid limitation of water use, a change in the flow mode of rivers in the regional water management system, the deterioration of water quality, and salinification of irrigated lands.

Intensively growing shortage of fresh water on the Earth, including Central Asia, associated with global climate warming, advances to the top priorities the search for ways and means of rational use of irrigation water, as well as the development of effective and environmentally safe methods of agricultural water supply [4]. The solution of these problems is directly related to the preservation of food and environmental security of the country.

Numerous studies, conducted mainly abroad, show that the drip irrigation of crops is indubitably the most effective method for the efficient use of irrigation water. Drip irrigation is an irrigation technique, in which water is evenly supplied in small portions to the roots of the plants throughout the growing season, and irrigation moisture is supplied directly to the plants and is not wasted in space between rows. Thanks to this, the drip irrigation system is more efficient than other irrigation methods.

In recent years, subsoil or subsurface drip irrigation systems become widely spread in agriculture. In these systems irrigation pipes are laid under the soil to various depths. With this method, pipes are less susceptible to damage during mechanical treatment of the soil and ensure minimal evaporation of moisture from the surface. The effectiveness of subsurface drip irrigation is proved by researches conducted in the United States, Australia, and India with regard to the cotton, potatoes, and other vegetable crops[5-8].

In terms of the moisture conservation and weed control, as is proved, use of mulch films at drip irrigation is quite effective. On the basis of these developments, the scientists of the State Research Center for Water Saving and Irrigation developed the drip irrigation technology under the mulch film. They have developed special device for simultaneous laying of drip irrigation belts, stretching mulch film and sowing of crops over the film[8, 9, 10].

Study of scientific-technical and patent literature concerned with drip irrigation shows that the available research focus mainly on the study of drip irrigation in growing vegetable and fruit crops. Number of research works studying efficiency of drip irrigation of field crops is much smaller, and they are considering mainly technical aspects of drip irrigation systems. A limited study of drip irrigation in field crops can be explained by the high cost of drip irrigation system and unprofitability for widespread use.

In this regard, we have conducted research in 2013-2015 on the effectiveness of drip irrigation of the sugar beet as the main industrial crops cultivated on irrigated lands of Southern and South-Eastern Kazakhstan.

Conditions, materials and methods

The aim of this work is to develop sugar beet cultivation technology based on drip irrigation, which would ensure the rational use of irrigation water, increase crop yields, reduce the cost of cultivation, preserve soil fertility and ensure environmental safety.

To that end, we faced the following tasks: to study the growth and development characteristics of sugar beet under different methods of drip irrigation; to identify the most effective planting techniques, to find out the optimal rates and timing of fertilizer application under different techniques of drip irrigation; to study the effect of different methods of drip irrigation on the weed infestation of crops, to establish the optimal irrigation mode, as well as to carry out agro-economic assessment of sugar beet cultivation efficiency under drip irrigation.

The studies were conducted at the field demonstration plots of the Knowledge Distribution Center "Ushkonyr" of the Kazakh Research Institute of Agriculture and Plant Growing (KazNIIZiR).

Permanent field study areas of KazNIIZiR are located near the city of Almaty in a hilly and rolling piedmont plains of Zailiyskiy Alatau, at the absolute altitude of 730 m.

The natural vegetation of the permanent field study area is characterized by absinthial and fescue.

Soil type is light-chestnut carbonate. Allocation of carbonates is in the form of whitish streaks, stains and holes in the horizon of 56-116 cm. Soil bubbling occurs from the surface.

Light-chestnut carbonate soils contain in the upper layer 2.5-2.7% of humus and 0.11-0.17% of nitrogen. The amount of humus decreases by depth. Containment of carbon dioxide of carbonates in the upper horizons of these soils is 2-3% and reaches a maximum (6-8%) in the carbonate-illuvial horizon. The amount of absorbed bases is 13-14 mg-eq per 100 g of soil. The main percentage in the absorbing complex belongs to calcium (Ca) (70-80% of the total absorbed bases).

An analysis of meteorological conditions over the study years (2013-2015) and their influence on the production process of the cultivars was carried out according to the data from meteorological station of KazNIIZiR.

Meteorological conditions during the study years were characterized by a large variety depending on vegetation months and had significant deviations from the long-time average annual indicators (Table 1).

By analyzing weather data over the years of research we come to the conclusion that agro-meteorological conditions were favorable for the formation of high yields of field crops.

To achieve the set objectives we laid down three field experiments with the following scheme (experiments 2, 3, and 4):

The total experimental plot area is 0.15 ha. Plot area is 14 m^2, three replications.

The research target was the French selection of Avantage sugar beet hybrid zoned in the RK.

Field experiments included the following surveys and observations: phenological observations over growth and development of sugar beet, field germination, plants stand density, and biomass accumulation dynamics, weediness of crops, definition of yield from trial sites (10 m^2), and the calculation of economic efficiency of various irrigation methods[11]. The resulting materials were subjected to structural and laboratory analyses. The mathematical processing of the harvest data was conducted according to the method of B.A. Dospekhov (1985)[12].

Drip irrigation systems were assembled in the experimental field in early May, while sowing was carried out during the second decade of May. For sowing we used precision seed drill laying drip tape and mulch film, produced by Xinjiang Keshen Agricultural Equipment Technology Development Co., Ltd.(China).

This seed drill can simultaneously perform eight operations, namely, aligning the field, laying drip tape, stretching mulch film, embedding the edges of the film with soil, carrying out perforation for precise sowing, sowing, covering the holes with soil, and compacting crop rows. The speed of cultivation combine is 3-4 km/h.

For seeding we used French selection of Avantage sugar beet hybrid zoned in the RK.

In options without mulch film we used three-stage chemical treatment: pre-emergent treatment with the Dual Gold herbicide, while during the growing season - two more treatments with the tank mixture Fusilade+Warrior+Lontrel were carried out.

Field experiments were laid by perennial grasses turnover. Farming technique generally accepted for a given zone consists of autumn plowing to a depth of 25-27 cm, the current planning, early spring harrowing, application of phosphorus fertilizers to create backgrounds, cultivation to a depth of 12-15 cm, and pre-sowing tillage to the depth of seeding (5 cm).

Sowing was carried out by 2ÂÌ£-4 drill (China), feeding was provided with ammonium nitrate long with drip irrigation water according to the scheme of experiments.

Harvesting was carried out at the technical maturity of sugar beet roots from all plots, whereas records were made based on trial site plots of 10 m^2 in triplicates.

RESULTS AND DISCUSSION

Phenological observations of the sugar beet crops showed that the shoots appeared on day 8-10. In drip irrigation options with mulch film the seedlings sprouted 1-2 days earlier than in other experimental options. The plant density in the period of seedlings ranged from 10 to 15 plants per running meter depending on irrigation and sowing techniques, while in the end of vegetation period the number of plants per running meter reduced to 8-12.

Control of weed infestation of sugar beet crops showed that the number of weeds varied widely depending on the irrigation methods. While in options with application of the mulch film, the number of weeds was 18-23 plants, without applying mulch film their number reached up to165 plants per each square meter. In these options, the use of herbicides was more effective than mechanical destruction of weeds. According to the methodology, the herbicides were applied in three stages: Dual Gold as pre-emergent herbicide, while a tank mix of Fusilade+Warrior+Lontrel - twice during growing season.

The number of weeds treated with herbicides decreased by the end of the growing season to 17-36 plants/m^2.

The species composition of weed plants was mainly represented by annual and perennial grasses dominated by yellow foxtail and bristle grass, while dicotyledonous weeds were represented mainly by pigweed, rocket-cress, cocklebur, lambsquarter goosefoot, and field milk thistle. Perennial grasses were represented by couch grass and scutch.

The accumulation of plant biomass can give an objective assessment of the sugar beet productivity dynamics. The study of the accumulation dynamics in the main growth and development periods of sugar beet plants showed that irrigation methods had a decisive effect on the accumulation of wet weight in terms of both sugar beet leaves and roots. The difference in the plants biomass accumulation rate depending on the irrigation methods can be traced back in the stage of forming two pairs of true leaves; thus, in the noted period, in the drip irrigation options with mulch film, biomass of individual plants was by

Table 1. Meteorological conditions during vegetation season of sugar beet

Indicators	Periods	Months						Total during the vegetation season
		April	May	June	July	August	September	
2013								
Air temperature, ^{0}C	average monthly	16.1	15.5	21.0	25.9	24.7	16.0	119.2
	mean annual	10.4	16.4	21.2	24.1	22.1	16.0	110.2
	deviation	5.7	-0.9	-0.2	1.8	2.6	0.0	9.0
Relative moisture, %	average monthly	62	52	63	43	37	43	300
	mean annual	65	63	60	51	50	54	393
	deviation	-3	-11	3	-8	-13	-11	-93
Rainfall, mm	average monthly	45.2	68.9	130.3	8.6	0	0.6	253.6
	mean annual	56.5	61.6	53.4	26.6	21.2	15.9	235.2
	deviation	-11.3	7.3	46.9	-18.0	-21.2	-15.9	18.4
2014								
Air temperature, ^{0}C	average monthly	12.3	16.9	21.3	24.9	23.6	19.9	118.9
	mean annual	10.4	16.4	21.2	24.1	22.1	16.0	110.2
	deviation	1.9	0.5	0.1	0.8	1.5	3.9	8.7
Relative moisture, %	average monthly	64	63	54	35	49	58	323
	mean annual	65	63	60	51	50	54	343
	deviation	-0.1	0.0	-0.6	-16	-0.1	0.4	-20
Rainfall, mm	average monthly	164.3	80.7	82.0	42.4	85.2	7.2	461.8
	mean annual	56.5	61.6	53.9	26.6	21.2	15.9	235.7
	deviation	107.8	19.1	28.1	15.8	64.0	-8.7	226.1
2015								
Air temperature, ^{0}C	average monthly	10.1	18.6	23.0	24.5	24.1	18.0	118.3
	mean annual	10.4	16.4	21.2	24.1	22.1	16.0	110.2
	deviation	-0.3	2.2	1.8	0.4	2.0	2.0	8.1
Relative moisture, %	average monthly	66	39	39	32	30	38	244
	mean annual	65	63	60	51	50	54	343
	deviation	0.1	-2.4	-2.1	-19	-20	-16	-99
Rainfall, mm	average monthly	106.7	58.8	35.3	4.2	0	10.8	215.8
	mean annual	56.6	61.6	53.9	26.6	21.2	15.9	235.8
	deviation	50.2	-2.8	-18.4	-22.4	-21.2	-5.1	-20.0

4.7- 17.9 g more than that in the control option with furrow irrigation.

The biomass accumulation in sugar beet lasts until September. At that, drip irrigation methods have significant influence on the plants biomass formation. We should note the positive effect of mulch film on the accumulation of biomass including both sugar beet tops and roots. At that, the most intense biomass accumulation was noted in plants subjected to surface drip irrigation with mulch film.

Crop inventory from each plot shows that drip irrigation leads to a very high harvest of sugar beet reaching up to 100 t/ha, whereas at conventional methods of sowing and irrigation the yield of sweet roots for three years has reached on average to 64.8 t/ha. It should be noted that indicated harvest is also quite high (Table 2).

As is obvious from Table 2, the irrigation and sowing methods had a significant influence on yield formation of sugar beet, as evidenced by the measurements of root yield.

During the years of the study (2013-2015), sugar beet has formed sufficiently high yields (64.8 t/ha) at conventional irrigation method. In the options of drip irrigation with irrigation belts arranged on the soil surface, the root yield reached 78.3-89.8 t/ha depending on planting system, while in the options with drip irrigation belts incorporated to a depth of 8-10 cm, the root yield ranged from

Experiment 2. Studying the efficiency of drip irrigation of sugar beet

Methods

1. Furrow irrigation (control);	1. Wide row sowing (60 cm) (control);	1. Mechanical treatment (control);
2. Surface drip irrigation;	2. Belt sowing 70 x 30 cm;	2. Chemical treatment;
3. Surface drip irrigation under the mulch film;	3. Belt sowing 80 x 40 cm.	3. Mulching technique.
4. Subsurface drip irrigation;		
5. Subsurface drip irrigation under the mulch film.		

The total experimental plot area is 0.2 ha. Plots area is 50-100 m^2, three replications.

Experiment 3. Studying the drip irrigation mode of sugar beet.

Irrigation rate, m^3/ha	Irrigation time
1000	Morning
2000	Day
3000	Evening
4000	Night
5000	

The total experimental plot area is 0.2 ha. Plot area is 14 m^2, three replications.

Experiment 4. Studying fertilizer application techniques, rates, and timing at drip irrigation of sugar beet

The rates and timing of nitrogen fertilizer application Rates of phosphorous fertilizer application,kg of active gradient per ha	P0	P45	P90
N0			
N30+30			
N30+30+30			
N30+30+30			
N30+30+30+30			
N30+30+30+30+30			

The total experimental plot area is 0.15 ha. Plot area is 14 m^2, three replications.

Table 2. Yield of sugar beet depending on sowing and irrigation methods, t/ha, (2013-2015)

Irrigation methods	Seeding methods		
	Wide-row seeding 60 cm	Belt seeding 30×70	Belt seeding 40×80
Furrow irrigation (control)	64.8		
Surface drip irrigation		89.8	78.3
Surface drip irrigation under mulch film		96.4	81.2
Subsurface drip irrigation		91.3	85.1
Subsurface drip irrigation under mulch film		82.8	76.3

Table 3. Harvest of the sugar beet roots depending on the mineral nutrition conditions, t/ha, (2013-2014)

Nitrogen fertilizer, kg of active gradient per ha	Phosphorous fertilizer, kg of active gradient per ha		
	0	P45	P90
0	68.5	92.9	83.4
N30+N30	97.9	96.5	93.3
N30+N30+N30	101.7	118.8	96.9
N30+N30+N30+N30	107.2	129.4	103.3
N30+N30+N30+N30+N30	102.3	116.7	97.4

85.1 to 91.3 t/ha. At that, belt planting system of 30x70 cm provides a higher yield (91.3 t/ha).

The highest yields of sugar beet roots were achieved at surface drip irrigation with application of mulch film, where yield amounted on average to 81.2-96.4 t/ha over 3 years. Though, in 2013, higher yields were achieved at subsurface drip irrigation. It is likely that the mulch films in some years may negatively affect the sugar beet plants growth and development during the period of intensive root formation. Perhaps, this is due to the biological characteristics of Avantage foreign selection, which forms a significant part of the root crop on the soil surface.

At the same time, the experiments on studying the efficiency of mineral fertilizers under drip irrigation of sugar beet with application of mulch film, showed sufficiently high yield, as evidenced by the data in Table 3.

Nitrogen fertilizers were applied in appropriate rates during the growing season using fertigation technique.

Fertigation is a method of plants fertilizing by supplying soluble minerals together with irrigation water.

In the course of fertigation technology, fertilizer is supplied to the plants directly with irrigation water; therefore, fertilizers are applied exactly to the sites of irrigation. Fertigation systems allow easy control of the optimal concentrations of fertilizers and their ratio, while these parameters can be controlled in automatic mode.

Data from Table 3 show that in two years the harvest of beet roots ranged on average from 68.5 to 129.7 t/ha depending on types, methods, rates and timing of application of mineral fertilizers. With the improvement of phosphorus nutrition conditions, the yield increased by 4.0 kg/m^2. The efficiency of nitrogen fertilizers was manifested most prominently on the background of phosphorus fertilizers. At high phosphorus background the increase in yield amounted to 50.9 t/ha. These data clearly indicate a multiple increase in efficiency due to applied fertilizers.

Noted efficiency of fertilizers can be explained not only by favorable conditions, created by drip irrigation, but also low provision of the soil at experimental plots with nitrogen and phosphorus. In these conditions, we may note also higher efficiency of phosphorous fertilizers as compared to nitrogen fertilizers.

We have also initiated the study of the drip irrigation modes of sugar beet at the best background of mineral nutrition. As can be seen from data presented in Table 4, the most effective irrigation rate is 2-3 m^3/ha.

The highest yield of sugar beet of 136.2 t/ha was obtained at irrigation rate of 3000 m^3/ha in a midday irrigation. Therefore, the most optimum mode of sugar beet irrigation is achieved by the fact that under drip irrigation in the midday the irrigation water in the irrigation belts is significantly warmed. This is beneficial to the growth and development of plants in the early development stages.

Calculation of agro-economic efficiency of applied technologies of sugar beet cultivation under drip irrigation has shown that increase of their intensity results in increase of production costs, including fertilizer, pesticides and fuel. However, because the yield of sugar beet also increases, this contributes to the increase of the total cost of the harvested roots crop.

Economic calculations have shown that

Table 4. Yield of sugar beet root crops depending on the drip irrigation conditions, t/ha

Irrigation rate, m^3/ha	Irrigation time			
	Morning	Midday	Evening	Night
	Average for 2013-2014			
1000	97.2	109.2	107.0	94.3
2000	109.2	120.5	120.0	104.7
3000	110.7	136.2	128.7	114.3
4000	104.5	135.3	120.7	123.9
5000	109.2	119.1	123.7	131.6

the net profit from 1 hectare of sugar beet at conventional cultivation technology amounted to 1164.2 thousand tenge, while at drip irrigation technology - 1480.1-1816.1 thousand tenge. The greatest profit per hectare of sugar beet is provided by drip irrigation under the mulch film.

Thus, the level of production profitability has increased depending on the irrigation and sowing technologies, and reached to 132%.

CONCLUSION

Sugar beet is a promising and highly profitable technical culture for South-Eastern Kazakhstan.

Using enhanced cultivation technology it is possible to get up to 129.4 t/ha of sweet roots with high sugar yields.

Drip irrigation technology is the best one when used under mulch cultivation of sugar beet. At that, the most optimal sowing method is considered to be the belt planting system 30x70 cm.

The sugar beet cultivation under the mulch film at drip irrigation reduces weed infestation of crops by 8-10 times as compared to the control.

The best time for drip irrigation is midday and the evening; at that, the optimum irrigation rate is 2000-3000 m^3/ha.

Drip irrigation under the mulch film provides a reduction in the irrigation water consumption up to 70-80% as compared to conventional irrigation methods, and increases the efficiency of fertilizer application by 2-3 times.

From an economic viewpoint, in terms of South-East of Kazakhstan, sugar beet is the most cost-effective technical cultivar at drip irrigation, providing on average 1718.0 thousand tenge of net profit for three years at the production profitability of 132%.

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