Permanent raised beds using; efficiency of direct seeding in the south–east region of Kazakhstan

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Abstract. Irrigated agriculture of the south eastern Kazakhstan requires a new technology of crop production with high economic efficiency. This study was conducted to determine technology of direct seeding on permanent raised beds, its impact on crop yields, and yield structure. The experiment was conducted with winter wheat (Triticum aestivum L.), soybean [Glycine max (L.) Merr.], and corn (Zea mays L.) in Zhambyl district of Almaty province during 2008–2011 growing seasons. The main point of new technology is use of ridges formed under cultivation of winter wheat during 5 years or more for direct sowing of the most common crops under irrigation conditions. Results of research have proved that direct seeding on permanent beds in comparison with a conventional method ensured higher efficiency, and good profit. Yields of winter wheat, soybean, and corn in total were accordingly 4.78, 3.48, and 9.27 t ha^{-1}. In this case resource–saving technology of crop production on permanent beds could become the diversification basis of irrigated agriculture in the south–east Kazakhstan. Introduction of this technology under conditions of the southeast will increase the productivity of irrigated land, and will make a difference in protecting of environment, production of ecologically pure, and competitive agricultural products.

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Introduction

Republic of Kazakhstan is the world's largest landlocked country by land area, and the ninth largest country. At the moment agricultural sector of Kazakhstan characterized by low productivity caused of low crop productivity, using outdated technology, and low innovation activity of the industry. Analysis of successful global practices in agriculture shows that the improvement of agricultural production results achieved through innovation. Taking into account the international experience, environmental conditions, and available resources in Kazakhstan as an optimal approach to the development of innovations in agriculture defined combination of foreign technologies transfer with own research.

In 1999 no–tillage farming, synonymous of zero tillage farming or conservation agriculture, was adopted on about 45 million hectares worldwide, growing to 72 million in 2003, and to 111 million hectares in 2009 [1]. Fastest adoption rates have been experienced in South America where some countries are using no–tillage farming on about 70% of the total cultivated area. Opposite to countries like the USA where often fields under no–tillage farming are tilled every now and then, more than two thirds of the area under no–tillage systems in South America is permanently not tilled; in other words once adopted, the soil is never tilled again [2,3]. The spread of no–tillage systems on more than 110 million hectares worldwide shows the great adaptability of the systems to all kinds of climates, soils and cropping conditions. In Kazakhstan the area reported by the Ministry of Agriculture under conservation technologies, including high disturbance conservation tillage, is more than 2 million hectares [4].

The current situation in irrigated agriculture in the southern and south–eastern regions of Kazakhstan called for fundamentally new, innovative approaches of crops cultivation on raised beds with furrow irrigation. Research studies of CIMMYT have proved the highly effective of crop cultivation on the ridges in many countries, known as "Bed planting–system" [5-11].

Studies conducted in 2001–2011 years in various irrigation zones of south and south–east Kazakhstan showed the high efficiency of winter wheat cultivation on the ridges [12]. The most rational way of sowing was 2–3-row seeding on ridges with seed rate 100 kg ha^{-1}. The most suitable for bed planting were local varieties Almaly, Zhetysu, and Erythrospermum 350. The main point of new technology is use of ridges formed under cultivation of winter wheat during 5 years or more for direct sowing of the most common crops under irrigation conditions, particularly corn and soybeans in the south, and south–east Kazakhstan [13].

In this regard became the necessity for comprehensive testing of this method in production conditions with development of new technology of wheat cultivation, corn and soybeans with using direct sowing on permanent beds.

Materials and methods

The field experiment was performed in 2008 to 2011 at the private farm "Svetlana" located in Zhambyl district of Almaty province. Total area was

15 hectares, including plots 8400 m^2 (length 600 m, width 14 m), and counted square 1260 m^2 (length 600 m, width 2.1 m) in three times repeatability.

The climate in this area is continental with cold winters, and hot summers (according to the Köppen classification). The mean annual rainfall was 280 mm, annual temperature 8.3°C, minimum -40°C, and the maximum was 42°C. The average sum of positive temperature during the growing period (April–September) was 3429°C.

The soil at the experimental site is light chestnut soil containing 2.1% of humus, 0.203% of total N, and 0.211% total P. Mechanical composition of this soil is heavy loam, with mobile phosphorus 23.4 mg kg^{-1}, exchangeable potassium 512 mg kg^{-1}, and 6.8 pH at the 0- to 30-cm depth [14].

Objectives of the study were Almaly cultivar of winter wheat, Zhalpaksay soybean sort, and Arman corn hybrid. Almaly cultivar is the middle ripeness, average winter hardiness cultivar approved for using in the south, and south–east parts of Kazakhstan. Zhalpaksay soybean sort belongs to the group of early ripening. Grain protein content 40%, oil content 19%. Sort drought resistant, heat resistant, early ripening, resistant to lodging, not fastidious to soil, suitable mechanized harvesting. Arman corn hybrid is medium–late ripening plant. All varieties – is the result of selection LLP "Kazakh Research Institute of Agriculture, and crop production" [15].

Scheme of the experiment was to compare the sowing methods such as conventional, and direct seeding on permanent beds on different crop cultures. First variant includes conventional sowing of winter wheat, corn, and soybean with the fertilizer rates N 45, P 45 kg ha^{-1}.

Four variants of the direct seeding with fertilizer rates:

1. NP 0.
2. N 45 kg ha^{-1}
3. N 45, P 45 kg ha^{-1}
4. N 45, P 23 kg ha^{-1}

Winter wheat was sown by conventional method with 15 cm of row spacing. Soybean and corn were sowed by wide row planting with spacing in 70 cm. On variants with direct sowing on permanent beds was used 70 cm of row spacing.

Results

The study of water–physical soil properties showed that methods of sowing had no substantially effect on the accumulation of moisture reserves in the first meter of soil (Table 1). More slightly accumulation of moisture in springtime was observed under variant with conventional method of sowing soybeans, and corn on the plowed soil.

Table 1. Water–physical soil properties at the various ways of sowing methods

Crop culture	Sowing methods	Moisture reserves in 0–100 cm of soil layer		Volumetric soil mass in 0–30 cm of soil layer	
		springtime	harvesting	springtime	harvesting
		mm		g cm^{-3}	
Winter wheat	Conventional	237	154	1.22	1.29
	Direct seeding	236	147	1.30	1.30
Soybean	Conventional	234	156	1.20	1.31
	Direct seeding	236	154	1.27	1.33
Corn	Conventional	252	153	1.19	1.34
	Direct seeding	248	142	1.27	1.32

Methods of sowing had a significant influence on the nitrate N content under sowings of winter wheat in early spring. The nitrate N content in soil at direct seeding was on 12.3 mg kg^{-1} less than at the conventional method (Table 2). This is primarily associated with possible suppression of nitrification processes in unplowed soil. Local adding of ammonium dihydrogen phosphate (ADP) simultaneously with direct seeding of crops pointed higher accumulation in the topsoil in spring, especially under soybeans, and corn.

Table 2. Content of mobile nutrients in the soil depending on sowing methods

Crop culture	Sowing methods	Nitrate N		Mobile phosphorus	
		springtime	harvesting	springtime	harvesting
		mg kg^{-1}			
Winter wheat	Conventional	42.4	13.8	22.6	17.4
	Direct seeding	30.1	12.5	22.1	18.6
Soybean	Conventional	53.6	14.6	25.4	19.0
	Direct seeding	44.9	17.4	30.8	22.3
Corn	Conventional	50.3	9.3	24.7	18.6
	Direct seeding	44.0	9.7	27.4	15.9

Sheaf analysis showed that yield of winter wheat formed due to plant density at conventional sowing, and due to productive tillering at direct seeding with equal values of the grain content in spike, and weight of 1000 grains (Table 3).

Table 3. Formation of winter wheat yield structure depending on the sowing methods

Sowing methods	Fertilizer rate, kg ha^{-1}	Plant density, plant per m^2	Productive tiller number	Grains per spike, units	1000-grain weight, g	Biological yield, g m^2
Conventional	N 45, P 45	189	1.77	42.4	43.6	59.2
Direct seeding	NP 0	104	2.60	36.4	40.1	39.7
	N 45	101	2.85	43.6	44.1	54.5
	N 45, P 45	96	3.27	43.0	44.1	59.8
	N 45, P 23	103	3.24	44.1	43.6	58.6

Soybean plants sowed on permanent beds after grain crops significantly ahead in the growth, and development of plants on variants with the conventional method of sowing (Table 4). The soybean on variants with direct seeding differed emergence of friendly seedlings, plentiful branching, and dark green coloring. The best growth, and development of soybean plants seeded on permanent beds provide more biological yield due to the amount of plants per area unit.

Table 4. Formation of soybean yield structure depending on the sowing methods

Sowing methods	Row spacing, cm	Rows	Plant per m^2	Plant height, cm	Amount of beans per 1 plant	Amount of seeds per 1 bean	1000-grain weight, g	Biological yield of 1 plant, g
Conventional	45	1	40.5	112.7	26.4	3.2	160.9	13.6
Direct seeding	70	2	48.8	114.8	25.3	3.2	152.7	15.4

Monitoring over the growing season of maize seed on ridges showed significant advance in the growth, and plant development. This is primarily related with the creation of favorable thermal conditions on permanent beds. The high rate of dry matter accumulation in corn plant was pointed in the phase of 10–12 leaves forming. High rates of dry matter accumulation in corn plant on the variant with permanent bed planting remained until the end of growing season, which finally contributed to the formation of higher productivity. Structure analysis revealed that crop at the variant with direct seeding on ridges had tendency of increasing cob size, quantity of grains per cob due to formation of rows, amount, and weight of grains per cob. Increasing of these parameters ultimately leaded to more output of grain, and corn harvest (Table 5).

Table 5. Formation of corn yield structure depending on the sowing methods

Sowing methods	Cob size, cm		Amount, units			Mass, g		grain output, %
	length	diameter	rows on the cob	grains in the row	grains in the cob	grains from the cob	1000-grain	
Conventional	16.3	4.6	12.7	36.9	469	130.7	273.7	84.8
Direct seeding	17.2	4.6	14.2	40.2	568	155.6	287.5	86.6

Yield data of crop cultures cultivated on permanent beds demonstrated the high efficiency of nitrogen fertilizer on winter wheat, and maize (Table 6).

On the variant with conventional sowing method of winter wheat was obtained 4.74 t ha^{-1} of grain. The best result at direct seeding obtained on variant with fertilizer rate N 45, P 45, and yield 4.78 t ha^{-1}. Conventional sowing of soybean and corn showed yields of 3.24, and 8.42 t ha^{-1} respectively. On variant at direct seeding with fertilizer rate N 45, P 45 the yield of soybean and corn were 3.48, and 9.27 t ha^{-1} respectively.

Economic analysis of the cultivation methods showed high efficiency of cultivation on permanent beds (Table 7). Product value from 1 hectare means actual market cost, and calculated by multiplying the yield on the price per tonne. Ratio of profitability calculated as net income divided by expenses, and multiplying on 100%.

Table 6. Crop yields depending on the sowing methods

Sowing methods	Fertilizer rate, kg ha^{-1}	Crop culture		
		Winter wheat	Soybean	Corn
		t ha^{-1}		
Conventional	N 45, P 45	4.74	3.24	8.42
Direct seeding	NP 0	3.15	2.46	5.62
	N 45	4.29	2.95	7.49
	N 45, P 45	4.78	3.48	9.27
	N 45, P 23	4.64	3.17	8.21

Table 7. Economic efficiency of sowing methods in the south–east Kazakhstan

Crop culture	Sowing methods	Yield, t ha^{-1}	Product value from 1 hectare	Expenses per 1 hectare	Net income	Profitability, %
			KZT*			
Winter wheat	Conventional	4.74	85300	43000	29700	69
	Direct seeding	4.78	86000	25700	42300	164
Soybean	Conventional	3.24	129600	65300	45100	69
	Direct seeding	3.48	139200	37000	71600	193
Corn	Conventional	8.42	126300	77700	34000	44
	Direct seeding	9.27	139100	40400	69100	171

* According the currency exchange rate 1 KZT=0.00676 USD on 03.06.2011.

Direct seeding of winter wheat, soybean, and corn on permanent beds in comparison with conventional method has showed almost 2 times fewer expenses, and almost 2.5 times more profitability of sowing technology.

Conclusions

The research of direct seeding on permanent beds in the south–east Kazakhstan has indicated many advantages: the most important of them is crop productivity increasing with fewer expenses, and higher profitability.

Therefore, cultivation of crops on permanent beds might be used as basis of irrigated agriculture system diversification with water-, and resource–saving technologies in the south–east Kazakhstan. Introduction of this technology under conditions of the southeast will increase the productivity of irrigated land, and will make a difference in protecting of environment, production of ecologically pure, and competitive agricultural products.

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