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*Recommendation on resource-saving technologies
of cultivation of cereal crops in the conditions of
rainfed agriculture in southern Kazakhstan*

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The recommendation summarizes the results of scientific-research works on substantiating the possibility of direct sowing of winter wheat with testing new herbicides during different periods of plants' development.

Models of technologies for winter wheat cultivation with minimizing tillage, ridge and furrow sowing method, which takes into account climatic conditions of rainfed agriculture in southern Kazakhstan, are proposed.

The opinions expressed here belong to the authors, and do not necessarily reflect those of Dryland Systems, ICARDA, or CGIAR.

The recommendations are intended for managers, specialists and farmers of various agricultural companies, researchers and students of higher and secondary educational institutions.

The recommendations were approved at the sessions of the Academic Board of the Southwestern Research Institute of Animal and Plant Breeding (Protocol No. 4 of 17 September 2014).

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Introduction

In the recent years, sown areas of grain crops have stabilized at the level of 220,000-250,000 hectares. The yield during the period of reforms of agriculture in the South Kazakhstan Region ranged from 7.9 to 21.6 centners/ha.

It is known that potential productivity of zoned varieties of grain crops in rainfed conditions reaches 40-45 centners/ha, and under irrigation - 80-100 centners/ha.

In new forms of agricultural companies, especially in small and medium-sized farms, because of objective and subjective reasons, usual recommended agrotechnology of cultivating agricultural crops cannot be maintained due to weak material and technical equipment status.

Therefore, at the imperatives of time and circumstances, it is necessary to revise the system of agriculture with minimization of soil treatments to direct seeding and zero tillage technology of cultivation. This research direction is expanding year after year in all states with market economy, as areas sown with agricultural crops increase.

In 2004, zero tillage technology in the world had reached 90 million hectares. If by the end of the 20th century these techniques were mainly distributed in North and South America, nowadays this system of farming is being actively introduced in such large countries as India, Pakistan, China and others.

In the south of Kazakhstan, resource saving technologies of cultivation of winter wheat with zero processing, that is, direct seeding and minimizing soil treatment, are among the new ones; research has been conducted since 2005.

SWRIAPB scientists have for the first time conducted a study, which aims to substantiate the possibilities of direct sowing of winter wheat in rainfed lands in southern Kazakhstan, with testing new herbicides at different periods of plants' development. The regularities of growth and development, and the character of formation of winter wheat efficiency in direct sowing compared to conventional technology have been identified.

For the first time, the competitiveness of new technology in relation to previously recommended technology in the region with economic and environmental justification for direct sowing of grain crops have been studied.

1. Technology of cultivation of winter wheat in direct sowing in conditions of southern Kazakhstan

The climatic conditions of southern Kazakhstan are sharply continental. The main amount of precipitation falls in autumn and winter periods. Depending on the amount of precipitation and vertical zoning, periods of sowing winter crops need to be addressed in a creative way, because the strategy of agrotechnology of winter crop cultivation depends on the nature of distribution and the amount of precipitation. The height of the future harvest depends on competent approach of a farmer, from sowing to full maturity of winter crops (Appendix A).

1.1 Winter wheat in rotation with direct seeding

Crop rotations and appropriate structure of sown areas should contribute to full utilization of soil moisture reserves during the growing season and getting maximum effect from controlled factors. This is ensured by optimal plant density, sowing methods, applying rational amounts of fertilizers, use of adapted varieties, and water-saving crop cultivation technologies.

In crop rotation, winter wheat is placed after perennial grasses (alfalfa), legumes (chickpeas), in highly rainfed areas on fallow field, in secured and half-secured rainfed areas on half-fallow and early fallow field, safflower, and in irrigated conditions after maize, soya and cotton.

In our research, winter wheat in direct sowing was cultivated in rainfed area after safflower, in irrigated conditions after alfalfa, and in ridge and furrow method after maize, with minimized soil treatments after vegetables and root crops.

1.2 Recommended varieties of crops for direct seeding

Problems of efficient use of arable land and increasing productivity of crops emerge when choosing crop varieties adapted to local soil and climatic conditions.

In this regard, we have researched and recommended the following varieties of spiked cereals, most adapted to local weather and climatic conditions of South-Kazakhstan Region (Table 1).

Table 1 - Agricultural zones of South Kazakhstan Region and recommended varieties of spiked cereals in direct seeding

Zones	Administrative districts	Recommended varieties
Secured rainfed zone (600 mm and more)	Tolebi, Tyulkubas, parts of Sayram and Kazygurt districts	Winter wheat Zhetysu, Yuzhnaya 12, Steklovidnaya 24, Oktyabrina70, Pamyat 47 (Dvuruchka — for winter sowing), Intensivnaya (Dvuruchka — for winter sowing)
Half-secured rainfed zone (400-500 mm)	Saryagash, parts of Sayram, Kazygurt, Baidybek and Ordabasy districts	Winter wheat Steklovidnaya 24, Krasnovodopadskaya 210, Oktyabrina 70, Pamyat 47 (Dvuruchka — for winter sowing)
Non-secured rainfed zone (200-250 mm)	Arys, Maktaaral, Otyrar, Sozak, Shardara, parts of Baidybek and Ordabasy districts	Winter wheat Steklovidnaya 24, Krasnovodopadskaya 210, Pamyat 47 (Dvuruchka — for winter sowing)

1.3 Timing, amounts and depth of seed placement in direct seeding

According to long-term average data, summer rainfall is extremely insufficient. It can be said that during June, July, August and September there is no effective rainfall. Starting from October, precipitation amount makes up 37 mm, in November - 52 mm and in December - 64 mm.

Because of global warming, weather and climatic factors in the conditions of southern Kazakhstan are also changing. As noted above, climatic conditions during summer months and early fall are formed very dry, making it difficult to perform primary and secondary tillage and resulting in delayed optimum time of sowing of winter wheat. In addition, rising prices of fuels and lubricants, and financial capabilities of manufacturers make adjustments in the technology of cultivation of crops.

Dry first half of fall, even with optimal planting dates (1st-2nd ten days of October) in rainfed areas makes level sprouts problematic.

Farmers, while sowing certified high reproductions seeds in dry soil, believe they will get full seedlings with precipitation. However, in dry autumn field germination is

reduced to 45-55% (seeds sown in optimum time and laying in dry soil for more than 30 days begin to lose viability, due to lower vigor). Therefore, it is very important to receive winter wheat seedlings in time, which will ensure level germination – this factor is directly linked to the height of the future harvest.

During direct sowing of winter wheat using stubble seeders SZS-2.1, soil moisture should be taken into account. Planting should start when upper layers of soil are moistened to the depth of 12-18 cm and the sowing machine moves freely with no resistance from soil-ground. This is very important in order to obtain level germination.



Photo 1 – Direct sowing of grain crops using SZS-2.1 seeder

For direct sowing in rainfed conditions of southern Kazakhstan, most adapted varieties are Steklovidnaya 24, Pamyat 47, Intensivnaya and Krasnovodopadskaya 210.

Terms of sowing winter wheat in humid years (with early atmospheric precipitation - 1st-2nd ten days of October) in South Kazakhstan Region come in the beginning of 3rd ten days of October, in medium-humid years - in the beginning of the 1st ten days of November, in dry autumn - in 2nd-3rd ten days of November.

Depending on vertical zoning, the rates of direct seeding of winter wheat should be approached in a differentiated way, taking into account biological characteristics of the cultivated varieties:

- for secured rainfed areas, 4 million viable seeds/ha are recommended;
- for half-secured rainfed areas, 3.5 million viable seeds/ha;
- for unsecured rainfed areas, 3 million viable seeds/ha.

These amounts are recommended for optimal sowing timing (2nd-3rd ten days of October and 1st ten days of November), in late November and early December these

seeding rates should be increased by 10-15%, at later stages recommended varieties are Pamyat 47 (dvuruchka) and Intensivnaya (dvuruchka), because these varieties show their highest productivity in late fall sowing.

Simultaneously with sowing, phosphate fertilizers should be applied in the amount of P_{20-30} kg/ha of active ingredient, which supports the development of root system and increased stability of winter wheat against unfavorable conditions of winter.

1.4 Agrotechnological methods of cultivating winter wheat in direct seeding

In spring, as soon as going in the field is possible, the density of wheat standing and its condition after wintering are determined. It is very important to conduct timely treatment with nitrogen fertilizers at the initial stage of renewal of spring vegetation. After wintering, weakened plants require enhanced nitrogen supply. The amounts of nitrogen fertilizers must be set as required, taking into account the differences between the soil and climatic conditions and zoning of South Kazakhstan Region.

The most rational amount of nitrogen fertilizers for unsecured and half-secured rainfed areas is N_{35} kg/ha of active ingredient. In secured rainfed area, the rate of nitrogen fertilizer should be increased 1.5 times - N_{50-60} kg/ha.

In direct sowing of winter wheat, an efficient agrotechnical methods is early spring harrowing, which improves the soil's water and air regime and contributes to rapid growth. It is necessary to consider the weather and climatic factors and phases of development of winter wheat, making adjustments to terms of agricultural operations. It is advised to hold harrowing in the full tillering phase in diagonal or perpendicular directions. The efficiency and productivity of winter wheat depends on competent and timely conduction of agrotechnological techniques.

With direct sowing, it is very important to organize activities to fight weeds, taking into account their specific and quantitative composition. It has been established that on direct sowing fields, the amount of weeds is significantly higher than on fields with conventional sowing technology.

In the conditions of southern Kazakhstan, more than 30 weeds can be found on fields sown with winter crops. In the recent years, after reforms in the agricultural sector and formation of various small and medium-sized businesses, the phytosanitary condition of grain crops has significantly deteriorated. This was due to ignoring previously recommended farming systems (science-based crop rotation schemes, primary and secondary tillage system, agrotechnical methods of cultivation, etc.). These circumstances require new approach to field works and cultivation of spiked cereals. Therefore, protection of plants from weeds becomes a farmer's paramount task.

The greatest damage to winter wheat in the conditions of southern Kazakhstan is brought by annual and perennial dicotyledonous weeds, and extensive damage is made by wild barley.

Years of research have proved timely application of a new generation of systemic herbicides is very effective in reducing contamination of crops (by 82-94%). Before the booting phase of winter wheat, at the initial phases of development of perennial and annual dicotyledonous weeds, it is recommended to use herbicide Dialen super 480 w.m. in the amount of 0.5-0.7 l/ha.

While applying herbicide to crops, climatic conditions (wind speed — max 5 m/s, temperature - above 14-16 degrees Celsius) should be considered. Besides, the treatment should be carried out in the morning and in the evening. The technical condition of the sprayer is also important, as the uniformity of application. Herbicide Topic 080 k.e. in the amount of 0.4-0.5 l/ha is very effective against wild barley. This weed gives seedlings in late autumn after cereal cultures, and dealing with it is very difficult.

Firstly, wild barley requires more moisture (consumes moisture 10 times its volume for seed germination), which explains late seedlings. Moreover, it tillers and winters very well. To determine the strategy to fight this weed using herbicides, one needs to be cautious in early spring periods, i.e. areas clogged with wild barley should be treated prior to its tillering.

For effective weed control, it is also recommended to use a mixture of herbicides Dialen super 480 w.m. - 0.6 l/ha + Topic 080 k.e. - 0.35 l/ha (binary package). Treatment of winter wheat with these combinations of herbicides at recommended application rates can help achieve high efficiency.

Dialen super 480 w.m., applied in the amount of 0.6-0.7 l/ha, is very effective against field peas, wild cabbage, bindweed, false carrot, bitterling and other dicotyledonous weeds. As noted above, Topic 080 k.e. (0.4-0.5 l/ha) effectively destroys wild barley, and it is very important to apply herbicide before the weed's tillering. If the time is missed and wild barley is treated in full tillering phase, it is able to give one full spike with developed grain.

The best effect against weeds in the conditions of southern Kazakhstan can be achieved using binary package of the named herbicides. This helps save costs associated with use of herbicides and effectively destroys perennial and annual dicotyledonous weeds, having a significant impact on suppression and suspension of grass weeds' growth .

Application of Diamin 72% w.m. in the amount of 1.25 l/ha and working fluid use of 250-350 l/ha in the winter wheat tillering phase and at early stages of development of weeds gives a significant effect. It is important that this herbicide has a sparing effect on the cultivated plant.

In the conditions of southern Kazakhstan, A mix of herbicides Istrebitel v.d.g. - 15 g/ha + Efiram k.e. - 0.4 l/ha is most efficient against annual and perennial dicotyledonous weeds, including those resistant to 2,4 D (thistle, Canada thistle, etc.).

1.5 Indicators of efficiency in direct seeding of winter wheat

Winter wheat in the conditions of southern Kazakhstan can be cultivated without full plough, where regulation of air and food regime, and timeliness of their quality performance, with introduction of a new generation of herbicides, provides consistently high yields at direct sowing with stubble seeders SZS - 2.1.

A powerful factor in direct seeding of winter wheat in the conditions of poor gray soils is timely early spring feeding with nitrogen fertilizers (N_{35} kg/ha). For example, when applying fertilizer with harrowing, grain yield increases to an average of 20.0 centners/ha, which is 4-5 centners/ha more than in traditional cultivation technology. According to SWRIAPB research, the highest grain yield — 25-27 centners/ha — was harvested during early spring application of fertilizer with harrowing and treatment of crops with herbicide Dialen super 480 w.m. (0.7 l/ha, working fluid flow rate - 350 l/ha). It has been established that consistent and timely agrotechnical care of the crop is very important. Thus, early spring feeding of winter crops on frozen-thawed soil and harrowing during physical ripening of the soil in the tillering phase, with subsequent treatment with herbicides and use of herbicide mixtures against dicotyledonous and grain weeds (Dialen super 480 w.m. at 0.7 l/ha + Topic 080 k.e. at 0.4 l/ha) ensured a fairly high grain yield, which averaged 25-27 centners/ha.

The research has shown that treatment of winter wheat against grain weeds with herbicide Topic 080 k.e. gave positive results in fighting weeds like wild barley, barnyard grass, foxtail, common bluegrass and others.

Thus, proper care during vegetation period, with consideration of species composition and targeted weed control, as well as cultivation of directly sown winter grain with stubble sowing machine without primary tillage is a fully justified agrotechnical method in gray soils of southern Kazakhstan.

1.6 Economic and energy evaluation of the effectiveness of direct seeding of winter wheat

The criterion of effectiveness of a particular agricultural technology of crop cultivation is their economic evaluation.

The most important indicators for identified economic evaluations of the studied agricultural practices are the costs of labor and resources.

The analysis of economic efficiency in direct seeding of winter wheat has shown usefulness of applying nitrogen fertilizers, harrowing and chemical treatment of crops with herbicides.

Thus, if in conventional approach direct costs per 1 hectare made up about 25,000 tenge, in direct seeding they decreased to 14,500 tenge. At the same time, conditional net income increased 1.9 times to an average 45,000-48,000 tenge with relatively low cost of 1 centner of production - 850-900 tenge, which is almost 1.7 times lower compared to conventional technology (1,500 -1,600 tenge).

When calculating the energy efficiency of technology of cultivation of wheat in rainfed conditions, total energy costs directly related to works on technological maps based on energy equivalents were determined. As a result, it was established that about 7-22% of energy costs are related to tillage and sowing; 3.4% to application of mineral fertilizers; 4-5% to herbicide treatment; 40-45% to cleaning and transportation of the crop; 44-46% to post-harvest grain processing.

The research of SWRIAPB scientists has found that applying fewer technological operations for pre-sowing land treatment in direct sowing ensured reduction of total energy consumption by 337,569 MJ, i.e. by 14%. Studies revealed that in direct sowing with applying mineral fertilizers and herbicides the costs increased to 2,608,654.81-2,662,091.3 MJ, or by 199,069.7-252,505.9 MJ/ha more than in traditional cultivation. The highest energy consumption rate was observed in the variant with fertilizers and herbicides. This is explained by increase in yield and associated costs of transportation and grain refinement.

The research results have shown that the energy stored in the wheat grain exceeded the energy cost for cultivation of this crop. However, variations with the traditional, conventional technology of cultivation and direct sowing with the exception of feeding, mechanical and chemical treatment, the energy received with grain yield averaged over three years at 2,568,487.4 and 2,441,170.2 MJ/ha, which only covers the cost of energy. The net energy return on these variants averaged, respectively, at 158,902.4 and 369,154.1 MJ/ha, where bioenergy coefficients ranged between 1.07 and 1.08; additional costs for harrowing, applying fertilizers and herbicides paid off with increased productivity, where increase of energy in the grain harvest amounted to 819,047.5-1,373,312.5 MJ/ha, which is 660,145.1-1,214,410.1 MJ/ha more than on the control.

The research has found that application of mineral fertilizers and use of herbicides did not require high energy costs, but gave the highest return on energy, where energy efficiency ratio reached 1.52 and 1.31.

Conclusion

With proper care during the growing season, with consideration of species composition and targeted weed control, cultivation of winter grain crops directly sown using stubble sowing machine without primary soil tillage is a fully justified agrotechnical method in rainfed gray soils of southern Kazakhstan.

The highest yield in direct seeding (25-27 centners/ha) is provided in the conditions of early spring feeding with harrowing and treatment of crops with herbicide Dialen super 480 w.m. in the amount of 0.7 l/ha at working fluid flow rate of 350 l/ha.

Early spring application of nitrogen fertilizers N_{35-50} kg/ha on the background of phosphorus P_{20-40} kg/ha on frozen-thawed soil and harrowing during physical ripening of soil in the tillering phase with subsequent treatment with herbicides and use of their mixtures against dicotyledonous and cereal weeds (Dialen super 480 w.m. at 0.7 l/ha + Topic 080 k.e. at 0.4 l/ha) provides a fairly high grain yield (24-25 centners/ha) in normally humid years and in rainfalls above normal in humid years 30 centners/ha or more.

Positive results in fighting grass weeds such as wild barley, barnyard grass, foxtail, common bluegrass and others are reached with using herbicide Topic 080 k.e. in the amount of 0.4 l/ha, ensuring reduction of contamination of crops by these malicious weeds by 94.7-95.5%.

Direct seeding reduces costs to 14,500 tenge, providing conditional net income in the range of 45,000-48,000 tenge and low cost of 1 centner of production - 850-900 tenge.

Түйін

Оңтүстік Қазақстанның кәдімгі сұр топырақ жағдайында күздік бидайды топырақты негізгі өңдеусіз тікелей егу мүмкіндігі анықталып, дақылдың даму кезеңінде арамшөптердің құрамына байланысты күресу шараларын жүргізу тиімділігі дәлелденді.

Күздік бидайды тікелей егуде ең жоғарғы өнімділік (25-27 ц/га) ерте көктемгі үстеп қоректендіру, тырмалау және Диален супер 480 В.Р. гербицидін 0,7 л/га мөлшерде қолданғанда алынды.

Ерте көктемгі үстеп қоректендіру және тырмалау, түптену кезеңінде Диален супер 480 В.Р. 0,7 л/га + Топик 080 к.э. – 0,4 л/га қоспасымен өңдегенде өнімділік деңгейі 25-27 ц/га артты.

Күздік бидай егіс алқабында кездесетін астық тұқымдас арамшөптерге қарсы Топик 080 к.э. гербицидін 0,4 л/га мөлшерінде қолданғанымызда егістің ластануы 94,7-95,5% дейін төмендеді.

Тікелей егуде шығын көлемі 14,5мың тенгеге үнемделіп, таза пайда 45-48 мың тенгені құрады, ал бір центнер өнімнің өзіндік құны 850-900 тенге болды.



Picture 2 - Direct seeding of winter wheat with application of mineral fertilizers



Photo 3 – Winter wheat sown directly with application of herbicide



Photo 4 – Winter wheat sown directly with application of mineral fertilizers in the amount of $P_{30}N_{50}$ kg/ha



Photo 5 – Directly sown winter wheat (Field day 2011)

Scheme of technological process of direct seeding of winter wheat in rainfed lands of southern Kazakhstan

Predecessor	Technological operations	Agricultural machinery and equipment*		Timing	Agrotechnical standards
Perennial grasses (alfalfa), legumes (chickpeas); In sharp rainfed fallow lands; In secured and half-secured rainfed fallow and early fallow lands, safflower	1. Seed treatment	Electrical current	PS-10 PSSh-5 mobitoks	2-3 weeks prior to sowing	Raxil – 0.4-0.5 l/ha Dividend extreme — 1.0 l/t Kolfugo super, 20% - 2.0-2.5 l/t
	2. Direct sowing	MTZ-80	SZS-2,1	3rd ten days of October, 3rd ten days of November	Direct seeding of winter wheat using stubble drills to depth of 4-5 cm; predecessor — safflower.
	3. Early spring treatment with mineral fertilizers	MTZ-80	RUM-3	February “windows” 1st-2nd ten days of March	On resumption of spring vegetation of winter wheat, application of nitrogen fertilizers in frozen-thawed soil : - for unsecured and half-secured rainfed lands - N ₃₅ kg/ha; - for secured lands – N ₅₀ кг/га Д.В.В.
	4. Closing moisture by harrowing	MTZ-80	BZTS-1,0	2 nd -3rd ten days of March 1st ten days of April	Early spring harrowing in the tillering phase before booting of winter wheat.
	5. Herbicide treatment in winter wheat tillering phase	MTZ-80	OVG-1a OPSH-1,5 POU	2 nd -3rd ten days of March 1st ten days of April	Herbicide treatment rates: Dialen super 480 w.m. - 0.5-0.7 l/ha Diamin – 1.25-1.5 l/ha Topic 080 k.e. – 0.4-0.5 l/ha Dialen super 480 w.m. – 0.6 l/ha + Topic 080 k.e. – 0,35 l/ha Istrebitel 0.15 g/ha + Efiram 0.4 l/ha
	6. Harvesting winter wheat	Niva, Laverda etc.	straw shredder	3rd ten days of June and 1st ten days of July	Direct harvesting with straw crushing and throwing on soil surface.
	7. Grain transportation	ZIL 130 KamAZ		June-July	Transportation of grain from field to barn-floor.

Recommended amounts and timing of treatment of grain crops with herbicides

Name of herbicide	Amount of treatment	Culture	Weeds	Timing of treatment
Dialen super 480 w.m.	0.5-0.7 l/ha	winter wheat, spring wheat, spring and winter barley	perennial and annual dicotyledonous weeds, including 2.4 D-resistant ones	from 3 leaves phase till end of tillering of grains
Topic 080 k.e.	0.4-0.5 l/ha	winter wheat, spring wheat, spring and winter barley	wild barley, wild oats, barnyard grass, foxtail, etc.	from 2-3 leaves phase to tillering phase
Dialen super 480 w.m. + Topic 080 k.e.	0.6 l/ha + 0.35 l/ha	winter wheat, spring wheat, spring and winter barley	perennial and annual dicotyledonous weeds, including 2.4 D-resistant ones: wild barley, wild oats, barnyard grass, foxtail, etc.	until the end of winter wheat tillering phase
Istrebitel v.d.g. (tribenuron-methyl 750 g/kg) + Efiram k.e.	15 g/ha + 0.4 l/ha	winter wheat, spring wheat, spring and winter barley	perennial and annual dicotyledonous weeds, including 2.4 D-resistant ones, thistle	spraying in spring during grain tillering phase until booting
Diamin 72% w.m.	1.25 l/ha	winter wheat, spring wheat, spring and winter barley	annual (pigweed, burweed, wormseed varieties, etc.) and perennial (field bindweed, thistle varieties) weeds	from the beginning of tillering until booting of the crop

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