RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
58 (3) 1367-1375, 2026
http://doi.org/10.54910/sabrao2026.58.3.39
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

PRIMARY TILLAGE AND MINERAL NUTRITION EFFECT ON SPRING BARLEY YIELD AND SOIL PROPERTIES UNDER RAINFED CONDITIONS OF KAZAKHSTAN

G.T. KUNYPIYAEVA[1*], R.K. ZHAPAYEV[1*], A.K. ALIMZHANOVA[1], ZH.A. MAZHENOVA[2], and A.M. USTEMIROVA[1]

[1]Kazakh Scientific Research Institute of Agriculture and Crop Production, Almaty, Kazakhstan
[2]Farabi University, Almaty, Kazakhstan
[*]Corresponding authors' emails: r.zhapayev@mail.ru, kunypiyaeva_gulya@mail.ru
Email addresses of co-authors: aliya_bade@mail.ru, mazhenova1981@gmail.com, zhanel-aigul@mail.ru

SUMMARY

In 2024, at the emergence stage, the productive moisture reserves with chisel tillage (30–35 cm) were 241.8 mm vs. 232.4 mm with traditional plowing (20–22 cm). In the dry conditions of 2025, these indicators decreased; however, the chisel tillage provided higher values at the emergence stage (203.4 vs. 197.6 mm). The soil density was lower with chisel tillage (1.13–1.28 g/cm³) than with plowing (1.15–1.29 g/cm³), revealing a more stable agrophysical condition. With chisel tillage and plowing and no fertilizers in 2024, the barley yield was 2.83 and 2.61 t/ha, respectively, while in 2025, the yield was 1.31 and 1.21 t/ha, respectively. Application of mineral fertilizer ($N_{60}P_{60}$) provided an increase of 0.62–0.95 t/ha in 2024 and 0.36–0.44 t/ha in 2025, while the growth stimulator (Beres Amino Max) further enhanced grain yield (4.34 and 4.03 t/ha). The determination of grain yield formation came primarily from crop seasons (80.0%) and fertilizers (16.6%), with a lesser influence of soil cultivation (2.07%).

Keywords: Tillage methods, soil water-physical properties, spring barley (*H. vulgare* L.), grain yield, soil density, climate change, drought stress conditions

Key findings: The integration of chisel tillage with mineral nutrition and growth stimulator provided higher and more stable yields of spring barley (*H. vulgare* L.) than in traditional plowing, especially under water-deficit conditions and climatic instability.

Communicating Editor: Prof. Dr. Zahoor Ahmed Soomro

Manuscript received: February 25, 2026; Accepted: May 17, 2026.

Citation: Kunypiyaeva GT, Zhapayev RK, Alimzhanova AK, Mazhenova ZHA, Ustemirova AM (2026). Primary tillage and mineral nutrition effect on spring barley yield and soil properties under rainfed conditions of Kazakhstan. *SABRAO J. Breed. Genet. 58 (3) 1367-1375. http://doi.org/10.54910/sabrao2026.58.3.39*.

INTRODUCTION

In the face of global climate change, an increasing determination of sustainable crop production depends on their ability to accumulate and effectively use stored soil moisture. Under such conditions, soil-conserving farming systems aimed at accumulating, preserving, and rationally using soil moisture achieved greater importance. Past studies of Southeastern Kazakhstan revealed that the soil cultivation system has a decisive influence on soil water regimes and stability of crops in dry seasons (Zhapayev *et al.*, 2023).

Soil-protecting methods of primary tillage, particularly chisel and subsoil tillage, surfaced as one of the most effective methods of water conservation. Subsoil tillage also preserves plant residues on the soil surface, reduces moisture evaporation, and protects the soil from overheating and water erosion. According to Kunypiyaeva *et al.* (2023), the use of chisel and flat-cutting tools helps increase productive moisture reserves in the upper one-meter soil layer, improve soil agrophysical properties, and develop a more stable water regime under the arid conditions of Kazakhstan.

The integration of chisel and subsurface tillage with spring fieldwork can significantly reduce moisture loss through evaporation, increase soil water-holding capacity, and ensure more uniform plant growth and development under low precipitation conditions (Zhapayev *et al.*, 2023). Introduction and optimization of chisel rippers and other resource-saving tools is one of the key areas that can effectively improve the soil structure, reduce compaction, and promote moisture accumulation in crops' root zone (Figure 1).

Chisel rippers ensure deep soil loosening without turning the layer, which enhances water permeability, improves capillary rise, and promotes a more uniform distribution of precipitation and meltwater within the soil profile (Kunypiyaeva *et al*., 2023). In turn, flat-cut cultivators minimize the soil structure disturbance and evaporation and preserve the plant residues on the soil surface, which enhances moisture conservation and increases the resilience of agrocenoses to abiotic stress conditions (Zhapayev *et al*., 2024). The effectiveness of such tools succeeded in their confirmation by both experimental data and theoretical studies demonstrating a positive impact on the hydrophysical properties of the soil and the growth potential of various crops (Zhapayev *et al*., 2025). The adjusted working parts allow for surface loosening while preserving mulch, which reduces evaporation rates and improves the microclimate in the soil environment (Lobell and Burke, 2010; Loke *et al*., 2022).

In the context of global climate change, the issue of sustainable grain production is becoming especially challenging.

Figure 1. Chisel ripper RC-2.3 and its primary tillage performance.

In arid regions, limiting crop productivity is largely due to moisture availability, particularly during the tillering and booting stages (FAO, 2021; Blum, 2011). Spring barley (*Hordeum vulgare* L.) is one of the most drought-tolerant grain crops with its short growing season, high plasticity, and ability to effectively utilize limited soil moisture (Ceccarelli *et al*., 2010). However, in spring barley, the realization of the genetic potential for drought tolerance mainly depends on agricultural practices and primarily on the hydrophysical and agrochemical properties of the soil.

The use of a chisel cultivator helps retain plant residues on the soil surface, reduces moisture evaporation, improves precipitation infiltration, and develops a stable soil structure (Hobbs *et al*., 2008; Kassam *et al*., 2019; Kunypiyaeva *et al*., 2023). Under these conditions, spring barley demonstrates more stable productivity indicators, an increased moisture use efficiency, and reduced sensitivity to short-term water stress. Thus, improving chisel-based tillage systems is a crucial element in adapting farming systems to increasingly drought conditions.

MATERIALS AND METHODS

Plant material and experimental design

For studying the different soil cultivation methods, the barley (*H. vulgare* L.) field experiments proceeded during 2024–2025 under rainfed conditions in Southeastern Kazakhstan. The study subjects, under semi-sustainable rainfed conditions, were the spring barley cultivar Symbat and soil cultivation methods—plowing at a depth of 22–24 cm and chisel tillage at a depth of 30–35 cm. The field experiments were in triplicate, placing the plots systematically. The sowing of barley seeds commenced in the last 10 days of March. The use of the Vence Tudo-7500 (Brazil) direct seeding seeder had simultaneous application of 100 kg of ammophos into rows. The plot area was 636 m^2. Just after sowing, the barley field entailed treatments with a glyphosate-containing herbicide (3 l/ha) against all types of weeds. During the growing season, treating the spring barley crop with the herbicide Efir Premium (0.5 l/ha) in a tank mixture with the growth stimulator BeresAmino Max (0.5 l/ha) continued. In spring and at the 3–4 leaf stage, the fertilization of barley plants with ammonium nitrate had a dose of 100 kg per hectare.

Study location’s description

The territory of Kazakhstan comprised a wide variety of natural and climatic conditions, with 80% of cultivated lands located in zones of insufficient moisture, including rainfed lands of Southeastern Kazakhstan. Based on annual precipitation, the rainfed lands undergo division into non-provided (with annual precipitation of 200 to 280 mm), semi-provided (280 to 400 mm), and provided (over 400 mm). In this case, the largest share falls on unsecured dryland farming (64%), with semi-secured and secured dryland farming accounting for 26% and 10%, respectively (Zhapayev *et al.*, 2023).

The presented research on the influence of tillage methods on the hydrophysical and agrochemical properties of soil took place in 2024–2025 at the Kazakh Research Institute of Agriculture and Plant Growing. The soil cover of the experimental area was foothill light chestnut soils formed on forest-like loams and has a defined fertile profile. A characteristic feature of light chestnut soil was its high carbonate content; effervescence was notable from HCl from the surface. On mechanical composition, the soil belongs to coarse-silty medium loams, with a physical clay content (39%–42%), coarse silt (45%–51%), and silt (12%–17%). The soil has an average supply of easily hydrolyzable nitrogen, low available phosphorus, and average exchangeable potassium. The soil’s upper horizon contains up to 2.02% humus and 0.12%–0.14% total nitrogen.

Meteorological conditions

A characteristic feature of the foothill plains climate was its sharp continentality, large daily and annual temperature fluctuations, and nonsignificant precipitation. The maximum precipitation occurs in spring and the minimum in summer. Winter precipitation accounts for 15%–25% of the annual total, and summer and autumn precipitation account for just 20% each. Maximum soil moisture reserves form by the beginning of spring fieldwork. Spring shows distinct thermal instability and frequent cold spells. Autumn is long and relatively warm. Average daily relative humidity in summer drops to 30%–34%. High temperatures and low relative humidity promote intense moisture evaporation, increased water transpiration by plants, and soil drying. Thus, the growing seasons of 2024 and especially 2025 consisted of a combination of elevated temperatures and insufficient precipitation, which developed stressful conditions for spring barley plants and emphasized the need for using moisture-saving and soil-protective cultivation technologies.

Data recorded and analysis

Achieving the study objectives succeeded through the implementation of field experiments and laboratory analysis. Conducting soil sample analysis ensued at the Soil Science and Agrochemistry Laboratory of the Kazakh Research Institute of Agriculture and Plant Growing. The field experiment establishment and observations proceeded according to the methodology of Dospekhov (1985). The determination of water-physical properties of the soil followed Kachinsky (1970). Three-factor analysis of variance (ANOVA) continued to compare the treatment variants for various parameters, with the treatments' differences considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

Soil water-physical properties

The world's cropland of 40% operates under water-stressed conditions, with nearly 60% of this arable land concentrated in areas particularly vulnerable to climate risks (Carbonell-Bojolloe *et al*., 2019). Under these abiotic stress conditions, the ability to utilize modern agricultural machinery and technologies to conserve and efficiently use soil moisture is a key factor in sustainable production. Soil conservation technologies contribute to improved water management and consequently increased crop yields (Wang *et al*., 2016). Surface mulching with plant residues during no-tillage plays a viable role in regulating water balance, as it enhances precipitation infiltration and significantly reduces moisture loss through evaporation (Jarecki and Lal, 2006). In arid regions, preserving productive soil moisture is especially important, where crop yield depends largely on the moisture reserves accumulated in the soil profile rather than on the moisture obtained through precipitation during the growing season.

The interphase reserves of soil moisture largely determine the stability of grain production under conditions of climatic instability (Dang *et al*., 2015). Furthermore, in previous years, one of the effective methods of soil cultivation has been deep chisel tillage. It facilitates no-till cultivation, promotes rapid penetration of precipitation occurring in autumn, winter, and spring into the arable soil layer, and soil moisture retention. In this regard, implementing the developed chisel cultivator is one of the most effective tools for adapting agriculture to climate aridity and precipitation deficit conditions, especially in regions with risky agriculture.

The results reflected the dynamics of productive moisture reserves during the spring barley vegetation phases under various primary tillage methods (Table 1). A comparison of traditional plowing (with a depth of 20–22 cm) and chisel tillage (with a depth of 30–35 cm) allows for assessing the effect of the depth and type of loosening on soil water conditions throughout the growing season. In 2024, during the emergence phase, higher values of moisture reserves were evident with chisel tillage (241.8 mm) than with traditional plowing (232.4 mm), revealing better moisture accumulation and retention during the crop's early growing stage. However, a similar trend persisted during the booting and heading phases, where moisture reserves with chisel tillage exceeded the moldboard tillage by 6%–10%. The results detailed the more efficient

Table 1. Dynamics of the content of productive moisture (mm) in the soil during the growing season of spring barley with different methods of primary soil cultivation.

Culture	Method of primary soil cultivation	Germination phase	Booting phase	Heading phase	The phase of full grain maturity
2024	Plowing to a depth of 20–22 cm	232.4	165.2	108.9	16.4
	Chisel 30–35 cm	241.8	171.7	114.7	15.2
2025	Plowing to a depth of 20–22 cm	197.6	119.7	92.3	31.3
	Chisel 30–35 cm	203.4	107.2	84.7	28.8

Table 2. Weather conditions for January-December 2024–2025, Almalybak Weather Station.

Month	Air temperature (°C)					Precipitation (mm)				
	2024	2025	Long-term means	±2024	±2025	2024	2025	Long-term means	±2024	±2025
January	-1.2	-2.6	-7.4	6.2	4.8	38.8	33.6	41.3	-2.5	-7.7
February	-4.0	-1.5	-5.3	1.3	3.8	43.6	17.1	44.6	-1.0	-27.5
March	5.4	6.2	2.8	2.6	3.4	135.5	76.8	64.7	70.8	12.1
April	12.8	17.7	10.9	1.9	6.8	111.3	57.2	110.6	0.7	-53.4
May	17.6	20.8	16.3	1.3	4.5	121.2	80.4	98.0	23.2	-17.6
June	24.5	25.6	21.2	3.3	4.4	19.7	17.1	59.0	-39.3	-41.9
July	25.0	27.7	23.7	1.3	4.0	23.7	9.6	56.9	-33.2	-47.3
August	25.9	24.9	22.9	3.0	2.0	25.1	17.9	34.8	-9.7	-16.9
September	15.1	18.9	20.9	-5.8	-2.0	14.3	47.0	25.9	-11.6	21.1
October	12.0	11.0	10.3	1.7	0.7	71.8	10.9	43.6	28.2	-32.7
November	1.5	5.7	2.0	-0.5	3.7	58.1	31.5	47.0	11.1	-15.5
December	-3.3	0.7	-4.4	1.1	5.1	45.5	51.7	46.1	-0.6	5.6
For the year	10.9	12.9	9.5	1.5	3.4	708.6	450.8	672.5	36.1	-221.7

use of autumn-winter moisture reserves and a considerable reduction in unproductive losses due to the preservation of soil structure and plant residues on the soil surface.

In the crop season of 2025, the weather exhibited less favorable moisture conditions, with absolute lower values across the spring barley crop growth and development phases (Table 2). However, the advantage of chisel tillage persisted during the emergence phase (203.4 mm vs. 197.6 mm), confirming its moisture-conserving effect during the initial stages of organogenesis. During booting and heading stages, the differences between the treatments diminished; however, the chisel tillage demonstrated more uniform dynamics, reflecting the stability of soil water regimes. At the spring barley's full grain maturity stages, higher values with plowing could be due to lower plant water consumption, despite a decrease in overall productivity.

These results were consistent with numerous past studies, according to which no-till and chisel tillage methods contribute to moisture accumulation in the upper one-meter layer, reduce evaporation, and improve soil permeability, especially in arid and semi-arid conditions (DeHaan *et al*., 2005; Berdahl *et al*., 2020). Similar conclusions were prevalent in other studies, which revealed that deep loosening without soil inversion enhanced the resilience of agrocenoses to moisture deficiency and provided more stable conditions for plant maturity during critical phases of growth and development (Zhapayev *et al*., 2023; Kunypiyaeva *et al*., 2023). In general, the results confirmed the feasibility of using chisel tillage as an element of soil-protective and moisture-saving technology, especially in conditions of inter-annual climate variability and limited moisture conditions.

Primary tillage plays a vital role in managing soil structure and soil water-physical properties, which significantly affect crop yield and the existing environment. Tillage can be a more effective method for reducing surface and

Table 3. Soil density and structure for spring barley under different tillage methods.

Year	Method of primary soil cultivation	Soil density (g/cm^3)		Soil structure (%)	
		Germination phase	Before cleaning	Agronomically valuable units	Water proof units
2024	Plowing to a depth of 20–22 cm	1.15	1.29	64.2	15.5
	Chisel 30–35 cm	1.13	1.28	61.1	14.3
2025	Plowing to a depth of 20-22 cm	1.14	1.29	58.8	16.2
	Chisel 30–35 cm	1.13	1.28	55.4	15.1

subsoil compaction (Tullberg, 2010). However, by comparing traditional moldboard plowing (20–22 cm) and chisel tillage (30–35 cm), further evaluation of the agrophysical variations in the soil under conditions of different mechanical impacts ensues.

In the crop season of 2024, at the emergence stage, the soil density was slightly lower with chisel tillage (1.13 g/cm³) than with traditional plowing (1.15 g/cm³), indicating a looser soil composition after deep, no-till loosening (Table 3). By harvest time, the soil density enhanced under both treatments; however, the differences between the tillage methods persisted in chisel tillage (1.28 g/cm³) and traditional plowing (1.29 g/cm³). A similar trend resulted in 2025, exhibiting a more stable agrophysical condition of the soil with chisel tillage.

Soil structure analysis revealed that in 2024, the share of agronomically valuable aggregates was higher with moldboard tillage (64.2%) than with chisel tillage (61.1%). Meanwhile, in 2025, a general decrease in this indicator appeared, which may be ascribable to drier conditions of the crop season. However, the relative ratio between both options remained (58.8% with traditional plowing and 55.4% with chisel tillage). The proportion of water-stable aggregates varied between 14.3% and 16.2%, with slightly higher values observed for the traditional plowing, especially in 2025. The study results were consistent with the previous research, in which the chisel and other non-moldboard tillage methods produced a less compacted but coarser-aggregate soil profile. In contrast, moldboard plowing contributes to a temporary increase in the proportion of small and agronomically valuable aggregates due to intensive mechanical soil destruction (Berdahl *et al*., 2001). Although the long-term use of chisel tillage contributes to stabilizing the soil structure, improving soil porosity and permeability, and reducing the risk of secondary compaction and degradation of the arable soil layer in the arid climatic conditions of Kazakhstan.

The results further enunciated that chisel tillage ensured lower soil compaction and stable agrophysical conditions during the crop-growing season, while traditional plowing produced slightly higher levels of structural parameters in the short term. Under moisture-deficit conditions, the advantage of chisel tillage was apparent by an increased stability of soil properties and the adaptability of agroecosystems. Increasing crop yield was the only one aspect of achieving food security, as intensive traditional production methods often have significant negative impacts on the ecological health of agroecosystems (Foley *et al*., 2011; Godfray and Garnett, 2014). In past years, several studies aimed at evaluating sustainable farming technologies, including minimum and zero-tillage (conservation agriculture), to reduce the negative impacts of traditional tillage.

In Southeastern Kazakhstan, field trial results revealed that minimum- and no-tillage systems promote the greater accumulation of productive moisture in the upper soil horizons than traditional plowing, proving particularly important for increasing crop stability under rainfed conditions. Local studies showed no-tillage maintained higher levels of soil organic carbon, which positively affects soil fertility and structural stability. However, the effect of no-tillage on crop yields may be uneven in the short term: initially, some decrease in the productivity of individual crops was evident, which may refer to the adaptation of plants and the soil environment to the new

Table 4. The influence of soil cultivation methods, mineral fertilizers, and growth stimulators on the yield of spring barley grains.

Methods of soil cultivation	Options	2024		2025	
		Grain yield (t/ha)	Increase (t/ha)	Grain yield (t/ha)	Increase (t/ha)
Plowing to a depth of 20–22 cm	Without fertilizers	2.61	-	1.21	-
	$N_{60}P_{60}$	3.56	0.95	1.65	0.44
	$N_{60}P_{60}$*	4.34	1.73	2.01	0.36
Chisel 30–35 cm	Without fertilizers	2.83	-	1.31	-
	$N_{60}P_{60}$	3.45	0.62	1.6	0.29
	$N_{60}P_{60}$*	4.03	1.2	1.87	0.27
$LSD_{0.05}$		0.214		0.163	

Note: *application growth stimulator "Beres Amino Max."

management system. However, in the long term, the integrated application of conservation agriculture results in a sustained increase in crop yield and improvement of soil properties (Pittelkow *et al*., 2015; Nurbekov *et al*., 2025).

Thus, the results reflected the influence of primary tillage methods and mineral nutrition levels on spring barley grain yield under contrasting crop seasons (Table 4). In crop seasons of 2024 and 2025, the chisel tillage showed an advantage over traditional plowing, especially under unfertilized conditions. Thus, in 2024, without applying fertilizers, the spring barley yield with chisel tillage was 2.83 t/ha, which was 0.22 t/ha higher than traditional plowing (2.61 t/ha). A similar trend continued in 2025 (1.31 vs. 1.21 t/ha), revealing more stable crop productivity with deep no-till loosening. Application of mineral fertilizers significantly increased the grain yield with both tillage methods, especially in the wet season.

Against the background of $N_{60}P_{60}$ in 2024, the spring barley yield increase with traditional plowing was 0.95 t/ha, and with chisel tillage, it was 0.62 t/ha. Additional use of a growth stimulator, Beres Amino Max, provided the maximum effect, with yields of 4.34 t/ha with plowing and 4.03 t/ha with chisel tillage. In the crop season of 2025, as characterized by less favorable weather conditions, absolute yield values were lower; however, the pattern of fertilizer effects remained, with increases of 0.36–0.44 t/ha with $N_{60}P_{60}$ and 0.27–0.36 t/ha with the growth stimulant treatment. In the dry year of 2025, the differences between tillage methods for yield equalized, but the chisel tillage ensured a more stable realization of production potential, as evidenced by lower yield losses than traditional plowing. Zhapayev *et al*. (2023) reported that no-till and conservation tillage methods contribute to better accumulation and retention of productive moisture, especially in crop seasons with insufficient precipitation. The presented results confirmed the statistical significance of the differences between the variants, primarily for fertilizer levels and, to a lesser extent, in terms of tillage methods.

Overall, the results revealed that the combination of chisel tillage with optimized mineral nutrition emerged as an effective element of soil conservation technology, ensuring an increase and stabilization of grain yield under the conditions of climatic instability and moisture deficiency. The three-way analysis of variance disclosed a significant influence of annual conditions, mineral fertilizers, and tillage methods on spring barley yield formation (Figure 2). The crop contribution to grain yield formation primarily depends on the crop season (80.0%), mineral fertilizers (16.6%), and tillage methods (2.07%), while random factors contributed only 1.33%. Therefore, one should note that spring barley grain yield formation was largely dependent on annual conditions and the use of mineral fertilizers, and this dependence increased due to weather conditions during crop-growing seasons.

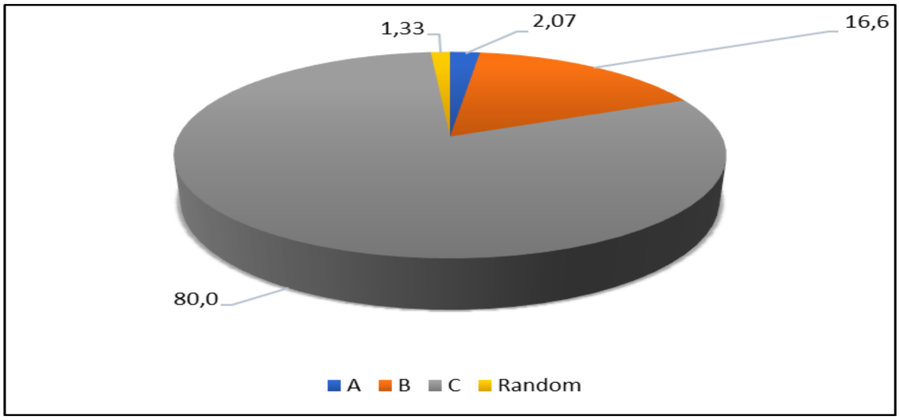

Figure 2. Three-way ANOVA of spring barley, where A- Soil cultivation, B- Fertilizers, and C-Year.

CONCLUSIONS

Establishing a reliable effect of soil cultivation methods and the level of mineral nutrition on the spring barley yield under diverse crop seasons with contrasting moisture availability was successful. In 2024, against an unfertilized background, chisel cultivation provided a yield of 2.83 t/ha and was 0.22 t/ha (8.4%) higher than traditional plowing (2.61 t/ha). In the dry crop season of 2025, the barley yield decreased to 1.31 and 1.21 t/ha, respectively; however, the advantage of chisel cultivation (0.1 t/ha) remained. Overall, the combination of chisel tillage and rational mineral nutrition increased yields by 1.20–1.73 t/ha in favorable cropping seasons and by 0.63–0.8 t/ha in the dry season, ensuring more sustainable grain production in rainfed farming conditions.

ACKNOWLEDGMENTS

The study proceeded within the framework of the program No.BR24892784, "Develop a system of machines, standards of need and fuel consumption for mechanized work, a planter for sowing sugar beets," funded by the Ministry of Agriculture of the Republic of Kazakhstan.

REFERENCES

Berdahl JD, Frank AB, Krupinsky JM (2001). Response of intermediate wheatgrass to management and environment. *Agronomy J.* 93: 915–922.

Blum A (2011). Plant Breeding for Water-Limited Environments. Springer New York, NY. 255. https://doi.org/10.1007/978-1-4419-7491-4.

Carbonell-Bojollo R, Veroz-Gonzalez O, Ordonez-Fernandez R, Moreno-Garcia M, Basch G, Kassam A, Torres M, Gonzalez-Sanchez EJ (2019). The effect of conservation agriculture and environmental factors on CO_2 emissions in a rainfed crop rotation. *Sustainability.* 11. 3955. https://doi.org/10.3390/su11143955.

Ceccarelli S, Grando S, Maatougui M (2010). Plant breeding and climate changes. *J. Agric. Sci*. 148(6): 627–637. https://doi.org/10.1017/S0021859610000651.

Dang YP, Seymour NP, Walker SR, Bell MJ, Freebairn DM (2015). Tillage in no-till farming systems in Australia's northern grains-growing regions: I. Strategic drivers and implementation. *Soil Till. Res.* 152:104–114. https://doi.org/10.1016/j.still.2015.03.009.

DeHaan LR, Van-Tassel DL, Cox TS (2005). Perennial grain crops: A synthesis of ecology and plant breeding. *Renewable Agric. Food Syst*. 20(1): 5–14. https://doi.org/10.1079/RAF200496.

Dospekhov BA (1985). Methods of Field Experience. M.: Agropromizdat: 351.

FAO (2021). Commission on Genetic Resources for Food and Agriculture (CGRFA). Rome. https://openknowledge.fao.org/handle/20.500.14283/ng840en.

Foley JA, Ramankutty N, Brauman KA, Cassidy ES, Gerber JS, Johnston M, Mueller ND, O'Connell C, Ray DK, West PC, Balzer C, Bennett EM, Carpenter SR, Hill J, Monfreda

C, Polasky S, Rockström J, Sheehan J, Siebert S, Tilman D, Zaks DPM (2011). Solutions for a cultivated planet. *Nature* 478: 337–342. https://doi.org/10.1038/nature10452.

Godfray HCJ, Garnett T (2014). Food security and sustainable intensification. *Philos. Trans. R. Soc. B*. 369. 20120273. https://doi.org/10.1098/rstb.2012.0273.

Hobbs PR, Sayre K, Gupta R (2008). The role of conservation agriculture in sustainable agriculture. *Philos. Trans. R Soc. Lond. B Biol. Sci*. 363(1491): 543–555. https://doi.org/10.1098/rstb.2007.2169.

Jarecki MK, Lal R (2006). Compost and mulch effects on gaseous flux from an alfisol in Ohio. *Soil Sci*. 171: 249–260. https://doi.org/.

Kachinsky NA (1970). Soil physics. Moscow: Higher School. Part II. Water-physical properties and soil regimes: 363.

Kassam A, Friedrich T, Derpsch R (2019). Global spread of conservation agriculture. *Int. J. Environ. Stud.* 76(1): 29–51. https://doi.org/10.1080/00207233.2018.1494927.

Kunypiyaeva GT, Zhapayev RK, Mustafaev MG, Kakimzhanov Y, Kyrgyzbay K, Seilkhan AS (2023). Soil cultivation methods' impact on soil water-physical properties under rainfed conditions of Southeast Kazakhstan. *SABRAO J. Breed. Genet*. 55(6): 2115–2127. http://doi.org/10.54910/sabrao2023.55.6.23.

Lobell DB, Burke MB (2010). On the use of statistical models to predict crop yield responses to climate change. *Agric. For. Meteorol.* 150: 1443-1452.https://doi.org/10.1016/j.agrformet.2010.07.008.

Loke PF, Heine HG, Rhode OHJ, Kotzé E, Du-Preez CC (2022). Tillage and its temporal effects on soil organic matter and microbial characteristics in the semi-arid central South Africa. *Soil Res.* 60: 294–309. https://doi.org/10.1071/SR21141.

Nurbekov A, Umarov S, Azizov S, Umarov M, Khaitov B, Khalilova L, Namozov F, Teshaboyev S (2025). Arid irrigated winter wheat and soybean cropping under conservation tillage systems. *Front. Sustain. Food Syst*. 9: 1512277. https://doi.org/10.3389/fsufs.2025.1512277.

Pittelkow C, Liang X, Linquist B, Groenigen K, Lee J, Lundy M, Gestel N, Six J, Venterea R, Kessel C (2015). Productivity limits and potentials of the principles of conservation agriculture. *Nature* 517: 365–368. https://doi.org/10.1038/nature13809.

Tullberg J (2010). Tillage: Traffic and sustainability – a challenge for ISTRO. *Soil Till. Res*. 111: 26–32. https://doi.org/10.1016/j.still.2010.08.008.

Wang Z, Liu L, Chen Q, Wen X, Liao Y (2016). Conservation tillage increase soil bacterial diversity in the dry land of northern China. *Agron. Sustain. Dev*. 36: 28. https://doi.org/10.1007/s13593-016-0366-x.

Zhapayev RK, Kunypiyaeva GT, Ospanbaev ZO, Sembayeva AK, Kyrgyzbay KA, Kakimzhanov YA (2024). Influence of tillage methods on soil water-physical properties under rainfed conditions of Southeast Kazakhstan. *IzdenisterNatigeler* 2-1: 220–232. https://doi.org/10.37884/2-1-2024/558.

Zhapayev RK, Kunypiyaeva GT, OspanbayevZh, Sembayeva AS, Ibash ND, Mustafaev MG, Khidirov AE (2023). Structural-aggregate composition and soil-water resistance based on tillage regulations in Southeast Kazakhstan. *SABRAO J. Breed. Genet*. 55(5): 1821–1830.

Zhapayev RK, Kunypiyaeva GT, Zhapparova AA, Kusainova MD, Ashirbekov MZh, Rahimgalieva SZh (2025). Optimization of soil cultivation to improve moisture conservation, structure and yield of agricultural crops. *Sci. Edu*. 1-2 (78): 85–96. https://doi.org//10.52578/2305-9397-2025-1-2-85-96.