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DEPENDENCE OF CROP YIELD ON ATMOSPHERIC PRECIPITATION IN THE RAINFED AREAS OF UZBEKISTAN.

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Abstract. The article discusses the efficient use of rainfed lands. Based on the analysis of long-term climatic conditions, the study examines the effect of soil moisture depth on the yield of agricultural crops grown in rainfed areas. It also describes the scientifically grounded optimal farming system. Taking into account farm land conditions, soil and climate characteristics, and the type of farming activity, the introduction of crop rotation schemes including cereals, clean fallow, and occupied fallow is justified as a means of increasing soil fertility.

Keywords: Rainfed areas, typical sieroz soils, climatic conditions, soil moisture, resource-saving technologies, clean fallow and occupied fallow, crop rotation system, cereal and legume crops, yield.

Introduction. Currently, rainfed lands worldwide cover about 1.4 billion hectares, accounting for 85–87% of the total cultivated agricultural land. These areas are mainly located in arid and semi-arid desert regions across almost all continents. In Asia, rainfed agriculture occupies a significant share of agricultural land: 95% in the Sahara region, 75% in the Near East and North Africa, 65% in East Asia, and 60% in South Asia.

In the Republic of Uzbekistan, rainfed agricultural lands cover 754.9 thousand hectares. Depending on the region, these lands are distributed at altitudes ranging from 200 to 1500–1800 meters above sea level. The annual precipitation in these areas ranges from 250 to 700 mm. Based on soil and climatic conditions and altitude, rainfed lands are divided into four zones, each characterized by a specific farming system.

Due to relatively low precipitation (200–600 mm), sharply continental climate, cold winters or long dry summers, and the fact that 60–65% of annual rainfall occurs in winter and early spring, the second half of the growing season of winter cereals (heading–ripening stage) takes place under soil and atmospheric drought conditions.

Under such conditions, photosynthesis processes in winter cereals and other crops slow down, resulting in smaller spikes, shriveled grains, and a sharp decline in yield.

In recent years, special attention has been paid to scientific research in many arid and semi-arid regions of the world on improving crop rotation systems, conserving natural soil moisture, and applying resource-saving soil protection technologies. To increase soil fertility, effective annual use of organic and mineral fertilizers is recommended. In particular, fertilizers are incorporated into the soil using appropriate tillage implements. Organic fertilizers are applied at a rate of 6–12 t/ha annually, while mineral fertilizers are applied at 45–60 kg/ha under winter

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wheat and inter-row cultivated crops in occupied fallow fields. The use of organo-mineral mixtures is also widely studied.

In rainfed farming, the correct selection and implementation of crop rotation schemes are essential for increasing grain yield and total grain production. Crop rotation is considered one of the most important agrotechnical measures for improving overall farming systems.

According to long-term experimental data, wheat yield after clean fallow in the first year reached 11.6 centners/ha; after occupied fallow, 7.4 centners/ha; in the second year after clean fallow, 7.3 centners/ha; and under continuous wheat cultivation, 5.8 centners/ha (Rafiev M., Aliboev A., Abdusalomov R., 1979).

In rainfed areas, the foundation for obtaining stable and high yields under various climatic conditions is the grain–clean fallow–occupied fallow crop rotation system. Within this system, it is essential to cultivate cereal, legume, and other rainfed crop varieties that are resistant to unfavorable soil and climatic conditions, diseases, and pests, and to grow them based on resource-saving agrotechnologies.

Research Object and Methods.

Research Object. The research was conducted on moderately eroded, medium loamy typical sieroz soils of the rainfed plain and foothill zone with partial precipitation supply. The winter wheat variety *Bakhmal-97* was used as the study material.

Research Methods. During the experimental years, soil and plant analyses were carried out according to the following methods:

- Agrochemical, agrophysical, and microbiological analyses – *Methods of Agrochemical, Agrophysical and Microbiological Research in Cotton-Growing Regions* (Tashkent, 1963).
- Selection of experimental plots and layout of treatments – *Methods of Field Experiments* (2007).
- Phenological observations and biometric measurements – *Methodology of the State Variety Testing of Agricultural Crops* (1985).
- Soil moisture – determined by the thermostat drying method at 105°C.
- Total humus – Tyurin method (modification of I.V. Tyurin and V.N. Simakov).
- Total nitrogen – Kjeldahl method.
- Total phosphorus – V.N. Lorenz method.
- Total potassium – flame photometry.
- Nitrate nitrogen ($N\text{-}NO_3$) – Granvald–Lyazhu method.
- Ammonium nitrogen ($N\text{-}NH_4$) – Nessler reagent method.
- Available phosphorus and exchangeable potassium – extracted with 1% ammonium carbonate solution; phosphorus determined by photoelectrocolorimetry (PEC), potassium by flame photometer.
- Total nitrogen, phosphorus, and potassium in plant samples – method of K.E. Ginzburg, G.M. Shcheglova, and E.V. Wulfus (1963).
- Plant biomass accumulation – V.A. Kumakov method (1982).
- Statistical analysis of experimental data – B.A. Dospekhov, *Methodology of Field Experiment* (Moscow, 1985).

Results and Discussion. Rainfed lands in the Republic are divided into four zones according to soil and climatic conditions and altitude above sea level. Each zone is characterized by a specific farming system. Due to low annual precipitation (200–600 mm), sharply continental climate, cold winters or prolonged dry summers, and the fact that 60–65% of total rainfall occurs in winter and early spring, the second half of the growing season of winter cereals (heading–ripening) proceeds under soil and atmospheric drought conditions. Under such conditions, photosynthesis in winter cereals and other crops decreases, leading to smaller spikes, shriveled grains, and a sharp reduction in yield. Based on long-term studies, A.F. Bolshakov

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(1950) concluded that in all rainfed areas of the Republic, the soil moisture regime is non-leaching (impermeable type). Below the wetted soil depth (1.5–2.0 m), a dry "dead layer" is formed, where moisture remains only at the level of capillary-bound water. The moisture regime of rainfed soils in the Republic has been studied in different years by A.A. Rode, A.F. Bolshakov (1950), S.N. Ryzhov (1953), Kh.M. Abduvokhidov (1962), S.M. Mamaniyazov (1967), A.S. Miloserdova (1978), M.Yu. Yunusov (1973), Kh. Yusupov (1990, 2001, 2011, 2014), and others. In Gallaaral district of Jizzakh region, rainfed typical sieroz soils are mainly formed on loess-like deposits and, less frequently, on fine gravelly proluvial deposits. The mechanical composition is predominantly medium loam, and in some cases light or heavy loam. The plow layer is clearly distinguished by its darker color and higher root density. The subsoil layers are carbonated, with the middle horizons more strongly carbonated than the upper and lower layers. Apart from the plow layer, the other horizons differ only slightly in moisture, color, and hardness. According to G.A. Lavronov (1979), in the foothill rainfed zone with partial moisture supply—covering more than 60% of the total rainfed lands of the Republic—the average annual precipitation is 325 mm, the average annual temperature is 11.6°C, and the average relative air humidity is 43% (data from the Gallaaral agrometeorological station, 1960). In rainfed areas, the yield of winter cereals and other crops largely depends on the distribution of atmospheric precipitation during the growing season. One of the key conditions for obtaining stable, high, and high-quality yields of winter cereals is timely sowing under optimal agrotechnical periods and ensuring that seedlings reach the full tillering stage before winter dormancy. According to long-term data (G.A. Lavronov, 1979), precipitation ranged as follows: October – 0–65 mm, November – 0–89 mm, December – 3–110 mm. In recent years, these values have fluctuated within 0–109.3 mm in October, 0–73.1 mm in November, and 2.6–142.5 mm in December.

Changes in Soil Moisture and Wheat Yield Depending on the Distribution of Precipitation During the Winter Wheat Growing Season

(Gallaaral, 1980–2024).

№	Climatic Characteristics.	Annual Precipitation, mm	Soil Layer, cm	**Soil Moisture, %**				Soil Moisture Penetration Depth, cm		Winter Wheat Yield, c/ha			
				After stubble (after cereals).		First year after clean fallow.							
				In Autumn (October)	In Spring (March)	In Autumn (October)	In Spring (March)	After cereal stubble.	First year after clean fallow.	After cereal stubble.		First year after clean fallow.	
										Without fertilizers.	N_{40} P_{40}	Without fertilizers.	10 t/ha manure + N
	Extremely Arid.	205,1	0-20	2,8	11,2	6,2	14,8	0-40	0-50	3,9	4,8	6,5	7,0
			20-60	4,2	7,8	7,8	9,2						
			60-160	5,4	5,8	6,4	8,6						
	Around the Long-Term Average.	362,4	0-20	5,8	10,8	6,9	14,3	0-80	0-100	11.0	15,5	14,7	21,8
			20-60	7,8	11,4	12,8	10,8						
			60-160	10,2	9,5	10	12,9						
	Extremely Wet Years.	505,7	0-20	10,2	15,8	10,8	12,8	0-130	0-155	11,8	14,9	19,4	29,4
			20-60	11,2	14,8	11,6	14,8						

			60-160	13,8	12,8	12,1	13,8						

It is well known that in rainfed areas, at the beginning of the winter cereal growing season (March), the moisture accumulated in the lower soil layers due to winter and early spring snow and rainfall, as well as the depth of soil moistening, is of great importance.

In the foothill rainfed zone with partial moisture supply, the soil moisture regime was studied depending on annual precipitation, its distribution during the growing season of winter cereals, and the applied agrotechnical measures.

Observations showed that in some extremely dry agricultural years, very low precipitation in October (4.0–5.2 mm) resulted in only 2.8–5.4% soil moisture in the plow layer by the sowing period. In such years, due to insufficient winter and early spring precipitation, the soil moisture penetration depth reached only 0–40 cm in fields sown after continuous cereals and 0–50 cm in fields sown after clean fallow.

Low precipitation in November during the study years reduced field germination and led to significant thinning of seedlings. In dry years (annual precipitation 205.1 mm), despite 92.6 mm of rainfall in October and November, low precipitation in spring (March–April) and hot, dry weather in May caused a sharp decrease in soil moisture (5.8–11.2%), resulting in reduced yields. A similar situation was observed in the 2010–2011 agricultural year, when soil moisture was 4.5–6.7% and yield amounted to only 3.0–5.5 c/ha.

In years when annual precipitation was close to the long-term average, uniform distribution of rainfall in late autumn, winter, and spring ensured soil moisture within the 0–100 cm layer at 5.8–10.2% in autumn and 9.5–10.8% in spring. This created favorable conditions during critical growth stages (flowering and milk–wax ripening), mitigating the negative effects of atmospheric drought. Wheat yield in such years ranged from 11.0 to 14.7 c/ha.

In wet years (466.3–488.9 mm and 501.9–542.0 mm of annual precipitation), abundant rainfall in late autumn (November), winter, spring, and especially in May (36.3–104.9 mm) led to soil moistening up to 0–160 cm depth. Such moisture conditions were highly favorable for winter wheat growth and development, resulting in high yields. Soil moisture reached 10.2–13.8% in autumn and 12.8–15.8% in spring, while wheat yield ranged from 11.8 to 19.4 c/ha.

In extremely arid years, the additional yield obtained from fertilizer application was only 1.0–2.1 c/ha. In years with precipitation close to the long-term average (303.0–357.5 mm), the yield increase due to fertilizers reached 3.8–8.7 c/ha. In wet years, this additional yield increased further to 5.3–10.2 c/ha. In these variants, the fertilizer-induced yield increase amounted to 142.4–170% compared to the unfertilized control.

Yield of Agricultural Crops (c/ha) in the Grain–Fallow Crop Rotation System of the Rainfed Zone Depending on Precipitation Amount.

№	Climatic Conditions.	Agricultura Years.	Annual Precipitation, mm	Winter Wheat (after clean fallow)	Legume and Forage Crops					Oil Crops			
					Chickpea	Alfalfa		Forage Pea		**Sunflower**		Safflower	Flax
					Grain	Green biomass	Grain	Grain	Green biomass	Grain	Green biomass		
1	Extremely Arid.	1985-1986	195,5	7,5	2,6	24,3	0,3	3,8	38,5	3,2	42,4	3,5	2,2
		2010-2011	181,9	6,5	2,1	21.0	-	7.0	21.0	1,8	31,2	3.0	2.0
2	Around the Long-Term Average.	1980-1981	348,8	18,9	7,5	75,3	1,3	14,3	65	7,8	171,3	7,5	6,5
		1986-1987	303.0	24,8	7,8	78.0	1,6	21,5	92,5	8,2	178,5	8,2	6,8
		1993-1994	336,4	21,8	7,5	84,7	1,4	18.0	128.0	7,8	155,7	8.0	6,2

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3	Extremely Wet Years.	1991-1992	480,0	26.3	10,0	112,4	1,5	20,5	185.0	11,1	205,3	10,5	9,8
		2001-2002	524.0	29,4	9.0	121,5	1,8	24,5	208.0	12,4	220,7	10,8	8,5
		2003-2004	425,4	24,5	11.0	115.0	1,6	18,5	170,4	11.0	215.0	9,5	8,2
	Average		353.0	19,8	6,9	79.0	1,1	15,1	113,4	7,7	151,2	7,5	6.0

In the foothill rainfed zone with partial moisture supply, the year-to-year variation in crop yields under the grain–fallow crop rotation system showed the following patterns.

In extremely arid years (1995–1996, 2010–2011, and 2020–2021), when the average annual precipitation was 181.9 mm, the average yields were: winter wheat – 6.5 c/ha, forage pea – 7.0 c/ha, sunflower – 1.8 c/ha, and safflower and flax – 2.5 c/ha.

In years when precipitation was close to the long-term average (1987–1988, 1996–1997, and 2003–2004), with an average of 336.4 mm of rainfall, the average yields reached: winter wheat – 21.8 c/ha, chickpea – 7.5 c/ha, forage pea – 17.9 c/ha, sunflower – 7.8 c/ha, and safflower and flax – 7.9 c/ha.

In years with precipitation above the long-term average (2009–2010, 2012–2013, and 2015–2016), when annual rainfall averaged 480 mm, the average yields were significantly higher: winter wheat – 26.3 c/ha, chickpea – 10.0 c/ha, forage pea – 20.5 c/ha, sunflower – 11.1 c/ha, and safflower and flax – 10.2 c/ha.

Conclusions.

1. In some extremely dry agricultural years, very low precipitation in October (4.0–5.2 mm) resulted in only 2.8–5.4% soil moisture in the plow layer, and seed germination was delayed until early spring.
2. In wet years (466.3–488.9 mm and 501.9–542.0 mm of annual precipitation), abundant rainfall in late autumn (November), winter, and spring—especially in May (36.3–104.9 mm)—led to soil moistening up to a depth of 0–160 cm. Such moisture conditions were favorable for the growth and development of winter cereals and for obtaining high yields. In these years, soil moisture reached 10.2–13.8% in autumn and 12.8–15.8% in spring, while wheat yield ranged from 11.8 to 19.4 c/ha.

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