MOISTURE CONTENT OF OATS IN DIFFERENT METHODS OF SOIL PROCESSING AND IRRIGATION TREATMENT ON THE FROZEN SOILS OF YAKUTIA OF THE RUSSIAN FEDERATION

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Abstract. The article presents the results of field research on the moisture content of oats under various technologies of soil cultivation and vegetative and water recharge irrigation. The aim of the research is to study the effect of irrigation, resource-saving soil cultivation technology on the moisture regime, the fertility of permafrost soils and the biological productivity of oats. Field experiments on the influence of the irrigation regime on the yield of oats were carried out on the cryogenic meadow-chernozem loamy soils of the Khangalasskydistrict, according to the effect of resource-saving soil cultivation technology on soil fertility - in the frozen taiga-pale soils of the Megino-Kangalasskydistrict of the Central Yakutia.Laboratory studies were carried out on the basis of a laboratory of biochemistry and mass analysis using the NIR SCANNER mo LCE 4250 spectral analyzer. In the conditions of the cryaridextracontinental climate of the Central Yakutia, the yield of crops depends on agroclimatic factors, where the average annual hydrothermal coefficient of the growing season is 0.90. The entire territory of the republic is included in the zone of continuous distribution of permafrost. The soil processes ensuring the growth and development of the vegetation cover are seasonal in nature and develop in the thawing soil of the summer, which is an active layer of permafrost landscapes.Low temperatures of the active layer interfere with the normal development of microbiological and biochemical processes in the soil. The studies included soil cultivation according to the traditional (plow processing) and resource-saving (multifunctional tillage aggregates) technologies, irrigation was carried out according to the main phases of plant development with the norm of 900 cubic meters per 1 hectare of the sowing area during the vegetation period and late-spring water-charging irrigation with the norm of 700 cubic meters per hectare.The efficiency of irrigation is established, which ensures an increase in the yield of green mass of oats by 20-30%. Resource-saving soil cultivation technology contributes to an increase in the supply of productive moisture

by 15.6%, a decrease in soil density by 4.2% and an increase in the yield of fodder crops. To improve the agrophysical properties of permafrost soils and increase the yield of fodder crops, it is recommended to use multifunctional soil cultivators and to irrigate oats on green mass.

Key words: *vegetative irrigation, moisture charging irrigation, soil moisture, productive moisture, permafrost soil, resource-saving technology, integrated tillage aggregates, fertility, productivity, soil cultivation.*

Introduction

Crop yields under the cryarid extracontinental condition in Central Yakutia depend on agricultural factors, where the average long-term hydrothermic coefficient equals to 0.90 [1]. The average long-term precipitation during the vegetation period (+5-+5◦C) in Central Yakutia is 152mm. The whole territory of republics falls under the continuous distribution of permafrost. Soil processes of the permafrost providing growth and development of flora have seasonal character, where active soil layer forms during the summer period via thawing. The low temperature of active soil layer contribute various outcomes such as the obstruction of the microbiological and biochemical processes in the soil, inhibition of the transformation of organic remnants and decrease in the rate of the biological compound and energetic cycles [2]. Specific conditions of Central Yakutia are short vegetation period and low temperature, poor soils defining reduced biological activity and fertility. These factors challenge the generation of novel methods for improvement of the soil fecundity and better crops yield.

Under permafrost condition in Central Yakutia, the agrotechnological method of soil processing by turnovers and spring field activities held 4-5 times annually contribute to the degradation of soil structure, fertility reduction, moist loss rise, and harvest decline, by means:

- Low-powered humus layer (5-20cm);
- Dry climate, low relative air humidity during summer season (30-70%) contributing to the intensive evaporation of soil moist and drying out of upper soil layers;
- The lowest available water supply in June, when the demand from plants to it is the highest (periods of sowing, seedlings, tilling);
- Particularly, high soil drought aftermath is observed on harvested crops at the autumn season, if there is low precipitation or under the permafrost taking place during the essential for plants growth and development periods (3rd decade of the May, June, 1st decade of July).

The resource-saving technology of soil cultivation with the usage of multifunctional units induce the crops fertility via improved moist saving, improves the soil structure, prevents its deformation and subsurface horizons compressions, enriches permafrost soils with organic materials.

Methods

Works on studying the rational usage of permafrost soils based on irrigation were carried out on Mundulakh experimental site of Megino-Kangalassky district located on the second floodplain terrace of river Lena in Prilensk agro-landscape.

Moidokh experimental site's soils belong to permafrost- solonchaks which develop along with permafrost meadow-chernozem alkaline soils [4]. pH_{wat}=7.6-8.4, humus content (by Turin) in arable horizon is 3,14%, mobile nitrogen (via ion-selective method) N_{nitr}=0,16, P_2O_5=18,2 and K_20= 27,2 mg per 100g of soil (via Egne-Rim).

Mundulakh experimental site's soils pH_{wat}=8,1-8,2, humus content in arable horizon is 2,92%, mobile nitrogen N_{nitr}=0,17, P_2O_5=16,4 and K_20= 29,7 mg per 100g of soil.

Post-processed topsoil is initially loose=1,23g/cm^3, then gradually condenses and reach the density up to 1,25-1,27g/cm^3.

The study was carried out according to methodic of field experience [5], accompanied with phenological, biometric monitoring and soil samples data [GOST 26205-86]; crop culturing agro-technique used was according to recommendation of Yakutian National Institute of Agriculture [6], laboratory experiments took place in laboratory of biochemistry and mass analyses using spectral analysis machine NIR SCANNER model 4250 (USA).

Observational sites on the effects of the irrigation on oat yield were located in five-field feed crop rotation. The experimental observation was divided followingly: control (no watering), watering (during major vegetation periods, with norm $300m^3$/ha) and late-autumn moisture charging watering with norm $700m^3$/ha.

Accounting plot's area was $21m^3$, with three times repetitions. Spring soil proceeding-moisture closing was carried in the 1st decade of May via disk harrow BDN-3 (rus.- БДН-3) with depth 8cm, introduction of mineral fertilizers in doze $(NPK)_{60}$ with preseeding embedment soil processing were carried in the 3rd decade of May by disk harrow BDN-3 with harrowing BZCC-1 (rus.- БЗСС-1). Oat sowing took place in the 1st decade of June by CNPP (rus.-СНПП) seeder with depth 4-5cm with following rolling out by ring roller. Watering was done by using KI-5 (rus.-КИ-5) sprinkler. Oats seeding norm was 200kg/ha).

Variants of experiments on influences of permafrost soil proceeding resource-saving technologies are following: traditional plow processing (control) and resource-saving soil processing technologies based on multifunctional soil-processing units. Experiment replications were done 3 times, experimental slot's area is 1,0 hectares.

Resource-saving technology was performed by complex unit APK-5,7 (rus.- АПК-5,7) in the autumn; preseeding processing and oat seeding with norm 200kg/ha; introduction of mineral fertilizer in doze $N_{60}P_{60}K_{60}$ kg **д.в./**kg, post-seeding rolling out were performed by multifunctional unit Ob'-4-3T (rus.-Обь-4-3Т) once during the 1st decade of June.

Results

In permafrost soils, under the underground ice lenses, the crop roots bulk is distributed on the top half-meter layer of soil [8], from which the soil's moisture foremost expenditure befalls (to physical respiration and plants transpiration) [9].

Experimental works on the influence of resource-saving technologies of soil processing in conserving moisture supplement and on the fertility of taiga-pale soils were carried out in 2009-2011 at Mundullakh site of Megino-Kangalassky district of Republic Sakha (Yakutia) in Russian Federation.

In 2009, weather conditions were advantageous for crops seeding, where May's precipitation was 41mm, which was two times more than long-term monthly average (19mm). On the second half of the summer, the precipitation was less than long-term average, hydro-thermic coefficient (HTC), was 0,73 during the vegetation period.

In May 2010, the precipitation was relatively higher than long-term average (26,4mm) in topsoil. During July, anomaly high temperatures (35-37◦C) were recorded. In August, precipitation was two times less than long-term average (24mm). HTC for June-July was 0,55.

Weather conditions in 2011 were prominent due to daily temperature differences in the first half of summer, where maximum daytime temperature could reach up from 32 to 38◦C. In May, precipitation recorded was 25mm with its long-term standard 20mm, in June- 22,0mm (standard 43,3mm) and in July- 64mm (standard 39,0mm). In August, monthly precipitation recorded was 85,0mm, which is two times higher than the average (41,0mm). HTC for vegetation period was 1,05 (Data obtained from Maya village weather station (Megino-Kangalassky district).

According to phenological and biometrical data obtained, optimal conditions for plants' growth and development via resource-saving soil processing technologies were highlighted. Under traditional soil processing advent of phenological phases were accelerated. Wherein, plants height from traditional dispensation (59,7-77,3 cm) was relatively lower than those under resource-saving soil processing (64,7-92,0cm).

Results showed, that in 2009 and 2010, the summarized water consumption under resource-saving technologies for soil processing was 143 and 120mm; under traditional technology 137 and 144mm respectively. In 2009, due to the late seeding, the total evaporation was significantly lower; total water expenditure at tilling phase in traditional processing was 80mm, wherein resource-saving type was 76mm; in 2010 water expenditure was 83 and 94mm respectively. Oats green mass harvesting under multifunctional soil processing was 6,7-7,7 t/ha, with yield increase by 0,8-1,0t/Ga compared with traditional soil processing. In 2011, under conducive moisture conditions (HTC- 1,05) total significant increase in water consumption under both types of processing was observed. For traditional processing, total water expenditure was 135mm, for resource-saving processing, the value reached 104mm. At the same time, the oats green mass yield was 11,9t/ha and 13,3t/ha respectively.

In general, with the usage of resource-saving soil processing of oats during the vegetation results in lesser moisture expenditure (120mm, 104mm) than in those processed by traditional methods (144mm, 135mm). This phenomenon is likely linked with higher moisture maintenance in bottom soil layers (table 1).

Table 1

Soil moisture stock dynamics under alternative soil processing, mm

Processing type	Soil later, cm	Moisture, mm			influx (+), expense (-), mm		
		13.05.	16.06.	25.08.	13.05.- 6. 07.	16.07.- 5.08.	13.05- 25. 08
2009 year							
Traditional Processing	0-20	33	24	26	-9	+3	-7
	20-50	42	40	41	-2	+1	-2
	0-50	75	64	67	-11	+3	-8
Evaporation, mm					80	57	137
Resource-saving processing	0-20	26	29	25	+3	-4	-1
	20-50	57	47	44	-10	-3	-13
	0-50	83	76	69	-7	-7	-14
Evaporation, mm					76	67	143
Precipitation, mm					69	60	129
2010 year							
		15.05	15.07	28.08	15.05- 15.07	15.07- 28.08	15.07- 28.08
Traditional Processing	0-20	47	23	22	-24	-1	-25
	20-50	71	62	44	-9	-18	-27
	0-50	118	85	66	-33	-19	-52
Evaporation, mm					83	61	144
Resource-saving processing	0-20	39	16	25	-23	+9	-14
	20-50	68	47	54	-21	+7	-14
	0-50	107	63	79	-44	+16	-28
Evaporation, mm					94	26	120
Precipitation, mm					50	42	92
2011 year							
		30.05	27.07	24.08	30.05-	27.07.-	30.05-

					27.07	24.08	24.08
Traditional Processing	0-20	31	11	16	-20	+5	-15
	20-50	61	24	38	-37	+14	-23
	0-50	92	35	54	-57	+19	-38
Evaporation, mm					113	22	135
Resource-saving processing	0-20	27	23	26	-4	+3	-1
	20-50	48	42	42	-6	0	-6
	0-50	75	65	68	-10	+3	-7
Evaporation, mm					66	38	104
Precipitation, mm					56	41	97

Under the traditional soil processing, the soil density by the end of vegetation (August) was 1,33g/cm^3, for resource-saving processing – 1,19g/cm^3. According to the data from the laboratory of agroecology in Yakutia National Institute of Agriculture, in resource-saving processed soils, the tendency for density decreasing of the 0-10cm topsoil layer was revealed. In general, years of research demonstrated the advantages of resource-saving technologies. Soil density (1,18g/cm^3) is less by 4,2% in topsoil than in those processed by traditional methods (1,23g/cm^3). (Table 2)

Table 2

Soil density, g/cm^3 (2009-2011)

Month	Soil layer, cm	Processing	Soil density, g/cm^3			
			2009	2010	2011	Average
May	0 – 10	Traditional soil processing	1,12	1,01	1,04	1,05
	10 – 20		1,20	1,18	1,06	1,14
July	0 – 10		1,36	1,36	1,27	1,33
	10 – 20		1,25	1,25	1,28	1,26
August	0 – 10		1,28	1,42	1,30	1,33
	10 – 20		1,27	1,27	1,27	1,27
Average			1,24	1,24	1,20	1,23
May	0 – 10	Resource-saving soil processing	1,09	1,01	1,00	1,03
	10 – 20		1,28	1,08	1,02	1,12
July	0 – 10		1,18	1,21	1,14	1,17
	10 – 20		1,32	1,34	1,22	1,29
Август	0 – 10		1,20	1,17	1,22	1,19
	10 – 20		1,32	1,28	1,30	1,30
Average			1,21	1,18	1,15	1,18

Experimental works on irrigation regime for crops green mass yield were held in 2015-2017 in meadow-chernozem alkaline soils.

The major limiting factor for crops yield under dry climate conditions is soil moisture in roots bearing layers.

By meteorological conditions, 2015 was exceptionally dry. In July precipitation was 14,2mm, in August- 21,8mm which is 2-3 times lower than long-term norm (53,7mm). HTC for vegetation period was 0,51. In 2016, the first half of vegetation period can be characterized as dry (in May-June total precipitation was 39,8mm compared with the norm of 42mm). In 2017, the beginning of vegetation's meteorological characteristics of weather were close to the norm, but starting from the second half of June precipitation was 2-3 time less than long-term norm. This phenomenon had a negative effect on plants development.

According to biometric data from 2015, the height of plants during in mowing ripeness with watering was 17,4cm higher than ones in dryland. In 2016, plants were 14,9cm higher (av=99,3cm) than in slot without autumn watering; in 2017, the height of plants (av=85,4cm) with irrigation was 7,9cm higher than in dryland.

On average, according to three years monitored data, plants height (av=82,0cm) in irrigated slots was 13,4cm higher than those in dryland.

In 2015-2016 despite the carried out autumn irritation (autumn 2015), root-habitable soil layers were comparatively dry in both slots 21-18 and 25-37mm, however, the moisture stick in the half-meter layer with irrigation was significantly higher (56,54,53mm) than dryland (table 3).

Table 3

Soil moisture stock dynamics with different irrigation types, mm

Irrigation type	Soil layer, cm	Moisture stock, mm			Influx (+), Expenditure (-), мм		
		18.06.	13.07.	18.08.	18.06-1307.	13.07.-18.08	18.06-18.08
2015 year							
No irrigation (control)	0-20	33	21	14	-12	-7	-19
	20-50	50	49	45	-1	-4	-5
	0-50	83	70	59	-13	-11	-24
Evaporation, mm					28	20	48
Vegetative irrigation	0-20	28	18	22	-10	+4	-6
	20-50	55	44	44	-11	0	-11
	0-50	83	62	66	-21	+4	-17
Evaporation, mm					36	5	41
Precipitation, mm					15	9	24
2016 year							
		08.06.	23.07.	31.08.	08.06.-23.07.	23.07.-31.08.	08.06-31.08.
No irrigation (control)	0-20	25	25	24	0	-1	-1
	20-50	48	50	48	+2	-2	0
	0-50	73	75	72	+2	+3	-1
Evaporation, mm					20	32	58
Moisture-charging irrigation	0-20	31	37	25	+6	-8	-6
	20-50	56	54	53	-2	-1	-3
	0-50	87	91	78	+4	-13	-9
Evaporation, mm					18	48	66
Precipitation, mm					22	35	57
2017 year							
		05.06.	14.07.	26.08.	05.06.-14.07	14.07.-26.08.	05.06.-26.08.
No irrigation (control)	0-20	82	49	62	-33	+13	-20

	20-50	76	91	96	+20	+18	+20
	0-50	158	140	158	-18	+18	0
Evaporation, mm					38	22	32
Moisture-charging irrigation	0-20	101	59	61	-42	+2	-40
	20-50	106	110	99	+4	-11	-7
	0-50	207	169	160	-38	-9	-47
Evaporation, mm					58	49	79
Precipitation, mm					20	40	32

In 2017, the highest soil moisture expenditure was observed during sweeping period in both variants (38mm, control and 58mm irrigation). On the other side, the peak growth of green mass in the absence (0,30t/ha) and presence (0,58t/ha) was noted. In consecutive growth phases, the variance in green mass accretion alleviates due to adequate precipitation.

Mowing ripeness' oat yield for three consecutive years was in following: with irrigation 12,2, 14,3 and 10,2t/ha and control (without irrigation) 8,3, 11,5 and 8,4t/ha, wherein the addition of green mass under irrigation was 1,8 to 3,9t/ha (table 4).

Table 4

Moisture expenditure at irrigation during vegetation period

Variant	2015 y.		2016 y.		2017 y.	
	Green mass, t/ha	Moisture expenditure, mm	Green mass, t/ha	Moisture expenditure, mm	Green mass, t/ha	Moisture expenditure, mm
No irrigation (control)	8,3	48	11,6	58	8,4	32
Irrigation	12,2	41	14,3	66	10,2	79
HCP_{05}	1,03		1,90		0,76	

Conclusion

Thereby, the usage of resource-saving permafrost soil processing improves the productive moisture by 15,6% compared with traditional soil processing technologies. Due to the decrease of soil density, agro-physiological properties of cultivating soils correspondingly improve.

Under the Central Yakutia's climate condition, oat is one of the most adapted cultivated crop, the yield of green mass in drylands is not less than 8,3t/ha, with irrigation it increases up to 12,2t/ha. With vegetative watering operated during the critical plant growth phases, the yield increases by 30-35%.

Water charging irrigation by itself can be described as an imitation of late-autumn abundant precipitation, due to its ability to supply a sufficient amount of moisture stock in root-bearing soil layers during the initial plant growth phases.

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