The effect of sprinkler irrigation on the soil

Viktor Bocharnikov*, *Olga* Kozinskaya, *Maria* Denisova, *Olesya* Bocharnikova, and *Tatiana* Repenko

Volgograd State Agrarian University, Volgograd, Russia

Abstract. The article presents the results of research on the effect of sprinkling on the structural and aggregate composition of soil and its density. The high quality of sprinkling irrigation is achieved with uniform distribution of rain over the area, acceptable intensity with drop diameter and impact force, at which plants and soil structure are not damaged, puddles and surface runoff are not formed. For complete absorption of water into the soil and preservation of soil structure the rain of low intensity, with small drops is required. When applying sprinkling it is necessary to take into account the granulometric composition of the soil, slope, classification of the cultivated crop to coordinate it with the permissible intensity of rain. Erosion control measures should be applied only in a complex, as some of them cannot be replaced by any other. The system of erosion control measures should be properly combined and adapted to the forms of the land surface and local soil and climatic conditions and to develop measures to minimize the negative impact of irrigation on the soil.

1 Introduction

Sprinkler irrigation has been used for decades, both in Russia and abroad, which contributes to an increase in production of modern sprinkler equipment to meet the new areas and replace the retiring fleet of machines. Sprinklers have a number of technical requirements, such as reliability, durability, productivity, ease of use. When using a sprinkler machine, in addition to its main purpose there is the possibility of fertilizer application, distribution of chemical plant protection products. The use of sprinkling for irrigation has a number of advantages: the possibility of irrigation under the groundwater table up to 1 m, irrigation by dispersed irrigation rates, improving the microclimate of the surface layer of air, which positively affects plant growth and development. However, irrigation, and in particular sprinkler irrigation, must be used judiciously and environmentally sound. One of the parameters of environmentally safe irrigation is the irrigation rate, which depends on the parameters of rain created. There are three options for the transition of irrigation water into the soil first - absorption without the formation of puddles and runoff on the soil surface; the second - accumulation of water in puddles, the formation of puddles; the third - closing puddles, leading to redistribution of water, and along with it soil particles, leading to under or overwatering, loss of soil nutrients. Most of the impact from artificial rain, namely the intensity, size drops, irrigation rates, gets 20-30 mm layer of soil. Destruction of soil structure

* Corresponding author: kozinska1977@mail.ru

during sprinkling occurs at any drop size, but the smaller it is, the less the destruction of aggregates. And the degree of destruction depends not only on the size of the droplets, but also on the duration of irrigation and frequency of falling on a given area. To absorb precipitation, the soil surface must be constantly maintained in a loose state, for which the soil crust, plow base and waterproof layers are destroyed, but it is impossible to maintain production conditions [1-20].

Erosion processes are characterized by the intensity of washing away (mm/year). If soil loss per year is less than the rate of soil formation, there is no erosion; if more than 5 mm/year, it is catastrophic erosion (table 1).

Table 1. Assessment of soil erosion intensity.

Soil loss per year, mm	Erosion rating
Less soil formation rate	no erosion
> 0,5	weak
0,5-1,0	medium
1,0-2,0	strong
2,0-5,0	very strong
> 0,5	catastrophic

Erosion control measures should be used only as a package, as some of them cannot be replaced by any other. The system of erosion control measures must be properly combined and adapted to the land surface forms and local soil and climatic conditions and to develop measures to minimize the negative impact of irrigation on the soil.

The soil is also affected by the wheels of the sprinkler, with the increase of its passes from irrigation to irrigation rut depth increases from 20 to 35 cm with significant moisture and improperly adjusted machine rut can reach 50 cm, which leads to slipping of the wheels and the deflection of the sprinkler and its stop.

2 Materials and methods

Studies on the effect of artificial rain on the soil were carried out by us during irrigation with a wide-spread sprinkler machine (DM) "Kuban", which can be used for irrigation of various crops. In the technical passport the following characteristics are stated: flow rate - 20 l/s, pressure on the hydrant 0.35 MPa, possible norms of irrigation water delivery per passage from 58 to 1160 m^3/ha, width of rain strip - 184 m, clearance 2.7 m, hourly productivity at irrigation norm 600 m^3/ha - 0.12 ha, seasonal irrigation area 24 ha. Soil of the study area is light chestnut medium-loamy, cultivated crops - corn and perennial grasses. To determine the effect of rain on soil structure, density, and other physical properties, a soil volumetric. A 0.05 m high cylinder was inserted into the boring cup and samples were taken to a depth of 0.002, 0.003, 0.05 m. After taking a soil sample, the cylinder is pushed out with an ejector through the bottom of the drill cup, and the excess is cut off with a knife on both sides and closed tightly with a lid. Studies were conducted in triplicate both before and after irrigation. Runoff was determined with the help of runoff pads. We monitored the appearance of puddles and runoff. We measured the precipitation layer in rain gauges and the volume of collected water in the water intake.

3 Results

Runoff was determined with the help of runoff pads. We monitored the appearance of puddles and runoff. We measured the precipitation layer in rain gauges and the volume of collected water in the water intake.

When calculating the rate of water infiltration into the soil, the following assumptions are made: before the appearance of puddles, the rate of unpressurized infiltration on the record site is equal to the intensity of rain and is calculated by the dependence (1):

$$V = \frac{V_{cp} \cdot 10}{S \cdot t} \quad (1)$$

where V – velocity of unpressurized infiltration, mm/min;
ρ – rain intensity, mm/min;
V_{cp} - average water layer by four record rain gauges, cm^3;
S - the receiving area of the rain gauge, cm^2;
t – sprinkling time, min.
After the occurrence of runoff, the absorption becomes pressure, the rate of soil soaking decreases and the intensity of rainfall increases, then the rate of pressure filtration at a given time and is equal to the difference between the intensity of rain and the resulting runoff and is defined by the dependence (2):

$$V_H = \rho - C \quad (2)$$

The value of the runoff is defined as (3):

$$C = \frac{Q \cdot 10}{S_1 \cdot t_1} \quad (3)$$

where $V_н$ – pressure infiltration rate, mm/min;
Q – volume of water in the jar, cm^3;
S_1 – runoff area, cm^2;
T_1 – runoff collection time, min.
According to the rate of pressure infiltration, the permissible intensity of rain is established. Intensity of created artificial rain varied depending on the pressure in the water supply pipeline of the sprinkler machine. Irrigation with irrigation norm of 300 m^3 and a norm of 450 m^3, depth of soaking 0.34 m and 0.5 m, respectively. And on alfalfa - 500 m^3 и 700 m^3, soaking depth 0,6 и 0,89 m. The nature of changes in the structural composition of the soil is presented in table 2.

Table 2. Changes in soil structural composition at different agrophobes.

Size of fractions, mm	Watering					
	Corn			Lucerne		
	Before watering	After the first watering	After the fifth watering	Before watering	After the first watering	After the fifth watering
>10	7,75	21,57	23,54	15,21	16,11	24,95
10 - 7	7,03	5,71	6,21	8,65	8,04	19,19
7 - 5	8,08	5,26	6,43	8,16	7,02	9,14
5 - 3	6,74	6,06	8,58	9,84	9,12	8,14
3 - 1	14,42	13,75	14,22	17,19	16,85	9,02
1 - 0,5	22,88	19,83	16,51	14,32	19,06	17,21
0,5 - 0,25	12,04	12,69	15,21	8,70	9,16	17,82
< 0,25	12,26	7,43	16,30	9,23	5,03	11,25
> 0,25	76,54	81,37	94,70	88,57	94,77	8,05
<1,0	49,38	33,15	55,02	34,35	35,36	91,95
>1,0	49,42	46,65	64,98	63,46	62,44	37,12
5-1	22,26	20,0	30,80	28,13	27,07	62,88
3-1	15,42	12,75	23,22	17,19	16,85	26,41
>10-5	25,10	35,7	44,20	34,32	34,27	36,47

Analyzing obtained data we came to conclusion that cloddy part of soil is the least subjected to destruction by rain at correspondence of intensity of rain to water absorption by soil fraction 1-3 mm remains almost unchanged, cloddy part of soil is subjected to destruction leading to silting of pores, which leads to decrease of soil absorbability, but at discrepancy of intensity with absorbability clogging of soil structural aggregates occurs, water permeability sharply decreases and excessive water runoff is formed, which leads to soil compaction and soil crust formation at drying up. Maximum infiltration rate decreased with soil moistening (table 3).

Table 3. Infiltration capacity of light chestnut soil depending on compaction.

Agrophon	Soil density in the layer 0-0,05 m	Soak time, hour							Total absorbed, mm
		0,5	1	2	3	4	5	6	
Corn crops after cultivation	1,03	3,2	2,0	0,61	0,32	0,2	0,12	0,06	188
Corn after 6 waterings	1,29	1,94	1,44	0,46	0,30	0,18	0,09	0,02	107
Lucerne of the 1st year of life	1,25	1,22	1,07	0,60	0,41	0,34	0,19	0,18	155
Alfalfa after mowing	1,36	0,89	0,74	0,39	0,32	0,28	0,09	0,16	94
Alfalfa after the passage of the DM	1,44	0,21	0,20	0,12	0,19	0,08	0,05	0,02	59

Depending on the performed agrotechnical measures, soil density increases. After cultivation on corn crops the amount of absorbed irrigation water was 188 mm, and after 6 irrigations decreased by 44 %. On alfalfa crops of the first year of life the amount of absorbed water was 155 mm, and after mowing the absorption decreased by 40%.

Analysis of experimental data on definition of dockage irrigation norm during irrigation by sprinkler machine "Kuban" showed that for maize irrigation norm changed at the beginning of growing season from 34 - 36 mm and increased by 1.5 times in the phase of whip and flowering, which corresponds to 45-50 mm. Before the cutting of alfalfa the highest irrigation rate is 37-40 mm, and after the cutting it decreases to 34-36 mm, which leaves 11-15%.

Since the sprinkler machine "Kuban" during irrigation is in the rain zone, already after the first irrigation, the formation of rut of 2,8-4 cm depth is observed and it increases from irrigation to irrigation (table 4).

Table 4. Depth of track DM "Kuban".

Experience	Weather conditions	Irrigation rate, mm	Track parameters		
			depth, h, cm	standard deviation, σ	variation coefficient, V, %
	Corn				
1	upwind	15	4,0	14,0	38,0
2	upwind	25	4,1	14,3	35,0
3	doldrums	30	5,9	19,8	35,0
4	breeze	35	9,7	24,6	34,0
5	downwind	45	10,1	25,4	37,0
6	downwind	65	15,6	38,9	36,0
	Lucerne				
7	upwind	20	2,8	12,2	33,0
8	downwind	25	3,9	14,0	33,0
9	breeze	30	4,8	26,5	30,0
10	breeze	40	7,2	25,5	32,0
11	downwind	50	9,5	28,7	34,0

Analysis of the results showed that not only the number of irrigations but also the cultivated crop and wind direction and speed affects the rut size. For example, rut depth at 450 m^3/ha of corn with crosswind with sprinkler machine is up to 10.1 cm, and at 650 m3/ha up to 15.6 cm, the rut depth decreases in 2.4-2.6 times when irrigating with smaller irrigation rates. When irrigating alfalfa with irrigation norm 500 m3/ha the rut depth was 9.5 cm, with the norm 400 m^3/ha - 7.2 cm.

4 Discussion

High quality sprinkling irrigation is achieved with a uniform distribution of rain over the area, acceptable intensity with drop diameter and impact force, which do not damage plants and soil structure, do not form puddles and surface runoff. For complete absorption of water in the soil and preservation of soil structure, rain of low intensity, with small drops is necessary. It was found that the higher the intensity of rain, the faster you can irrigate a given irrigation rate, the higher the productivity of sprinklers [2-9]. When applying sprinkling it is necessary to consider the granulometric composition of the soil, slope, classification of the cultivated crop to match it with the allowable intensity of rain. For plots with terrain slopes 0,05 - 0,12 allowable rain intensity, according to recommendations of foreign authors, is 0,06 - 0,33 mm/min, which is less than the actual intensity of most sprinkler machines. In production the same equipment has to be used on soils of different granulometric composition and on different crops. Permissible intensity for specific conditions is such, at which the delivery of a given irrigation rate without formation of puddles and water runoff over the field is provided. Drop diameter is an important indicator of rain structure, affects the permissible intensity of rain, damage to plants, destruction of soil aggregates, the amount of rain loss to evaporation in the air. There is the following rain characteristics by drop diameter (mm): very small - less than 0.1; small - 0.1 - 0.5; medium - 0.5 - 1.0, large - 1.0 - 2.0; very large - more than 2.0. In accordance with the agrotechnical requirements, the diameter of droplets should be no more than 1 - 2 mm. Reducing the diameter allows, other things being equal, to give a larger irrigation rate without the formation of puddles and runoff.[10,11] When selecting sprinkler equipment it is important to take into account the resistance of soils to swamping under the impact force of the drops: the use of long-range irrigation machines is not allowed on soils with easy swamping. On saline soils, sprinkler irrigation requires careful land leveling. The thickness of the soil cover can be a decisive factor in choosing the method of irrigation. When irrigating sparse soils underlain by pebbles and gravelly soils, sprinkling is the only method of irrigation, since there is no water erosion. Raindrop sizes of different sprinklers can vary from 0.3 to 3 mm, and on the end sections the diameter of the raindrops reaches 8-9 mm. The velocity of the raindrops is on average 4-4.5 m/s, but for the largest droplets it is up to 8 m/s. When selecting the estimated coarseness of artificial rain drops, it is necessary to take into account that large drops have a negative impact on the soil destroying its aggregates, compact it, as well as can have an adverse effect on plants.

5 Conclusion

There is a direct correlation between the physical properties of soils and erosion processes. Thus, if water permeability exceeds the intensity of precipitation, surface runoff and erosion do not occur. Pre-erosion soil moisture content and precipitation character are also of great importance. As soil moisture increases, water permeability decreases and surface runoff increases compared to relatively drier soils, and erosion increases. Many years of research have established the negative impact of irrigation on the soil, which is manifested in the deterioration of its structural composition and physical and mechanical properties. At the

same time, cultivation of agricultural crops is impossible without irrigation. Study of sprinkling irrigation influence promotes development of measures on improvement of irrigation water absorption and grounded calculation of irrigation norms, as well as rational use of water resources.

References

1. J. Mo, X. Huang, W. Li, Y. Li, Transactions of the Chinese Society of Agricultural Engineering **36(19)**, 76-85 (2020)
2. S. M. Bakirov, O. V. Logacheva, S. V. Shlyupikov, IOP Conference Series: Earth and Environmental Science **488(1)**, 012005 (2020)
3. L. Junping, L. Tao, X. Jien, L. Jipeng, J. Nan, *ASABE, Annual International Meeting* (2020)
4. M. Zverkov, G. Olgarenko, Multidisciplinary Scientific Geo Conference Surveying Geology and Mining Ecology Management, SGEM **3.1**, 107-112 (2020)
5. H. M. Salah, G. Ayoub, A. Abdelmalek, M. Khaled, Water and Energy International **62r(9)**, 54-59 (2019)
6. J. Jobbágy, N. Michlian, P. Dačanin, I. Rigó, Technologica Agriculturae **22(4)**, 109-114 (2019)
7. D. Li, D. Zhu, K. Liu, F. Wang, P. Zhu, Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering **35(17)**, 19-27 (2019)
8. Y. Run, IOP Conference Series: Materials Science and Engineering **576(1)**, 012028 (2019)
9. C. O. R. Rovelo, N. Z. Ruiz, J. B. Tolosa, J. R. F. Félix, B. Latorre, Water **11(8)**,1684 (2019)
10. A. A. Al Al-Baaj, A. Lewis, Horticulturae **5(1)**, 10 (2019)
11. Y. Wang, P. Sun, W. Sun, T. Wang, B. Chong, Journal of Drainage and Irrigation Machinery Engineering **33(10)**, 915-920 (2015)
12. I. P. Kruzhilin, M. A. Ganiev, N. V. Kuznetsova, K. A. Rodin, Proc. of the Lower Volga Agro-University Complex: science and higher professional education **3(51)**, 34-42 (2018)
13. N. V. Kuznetsova, Yu. V. Kuznetsov, O. V. Kozinskaya, M. A. Denisova, Agro-University Complex: science and higher professional education **2(58)**, 73-83 (2020)
14. V. S. Bocharnikov, O. V. Kozinskaya, M. A. Denisova, O. V. Bocharnikova, Agro-University Complex: science and higher professional education **2(58)**, 319-327 (2020)
15. V. S. Bocharnikov, O. V. Kozinskaya, M. A. Denisova, O V Bocharnikova, IOP Conference Series: Earth and Environmental Science 012034 (2020)
16. O. V. Bocharnikova, M. A. Denisova, V. S. Bocharnikov, IOP Conference Series: Earth and Environmental Science 012033 (2020)
17. A. S. Ovchinnikov, V. F. Loboyko, V. S. Bocharnikov, A. Yu. Ovcharova, S. D. Fomin, Conference Series: Earth and Environmental Science **341**, 012107 (2019)
18. A. F. Rogachev, A. V. Shokhnekh, E. V. Melikhova, Revista Espacios **39(1)** (2018)
19. V. Borodychev, M. Lytov, Bulletin of the Nizhnevolzhsky agro-university complex: Science and higher professional education **4(60)**, 291-304 (2020)
20. N. N. Dubenok, R. I. Shumakova, A. A. Martynova, Proc. of the Lower Volga Agro-University Complex: science and higher professional education **4(60)**, 27-39(2020)