Management of the water regime of soil to increase the vegetable crops yield with different irrigation methods in the south of Russia

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Abstract. Long-term researches on the cultivation of vegetable crops with different methods of irrigation in the Volgograd region have shown that their yield was primarily closely related to the improvement of the water regime of the soil. Its efficiency using drip irrigation increased with the introduction of mineral fertilizers, and using subsurface irrigation - with an improvement of the location of the irrigation network. The highest yield of beet with drip irrigation (82.4 t / ha) was obtained with an increase of the Soil Pre-Irrigation Moisture (SPIM) to 85% of Full Moisture Capacity (FMC) and fertilization doses - to N235P140K130 kg/ha. The highest yield of courgettes with drip irrigation of 83.7 t / ha was obtained while maintaining the similar irrigation regime and the quantity of fertilizers N240P99K110 kg/ha.The maximum cabbage yield in our experience with drip irrigation of 83.1 t / ha was achieved using the option that combines the maintenance of the irrigation regime 80-90-80 %FMC with the application of fertilizers at doses of N110P50K140 kg / ha. The highest yield of radish with subsurface irrigation of 79.8 t / ha was obtained while maintaining SPIM 85 % FMC in the field with the location of subsurface humidifiers at a distance of 1.2 m from each other.

1 Introduction

Vegetable growing is the most important branch of agriculture in the Russian Federation. The Volgograd region is a typical region of the south of Russia, which is one of the main suppliers of vegetable products to various regions in our country. However, due to the strongly arid conditions, the cultivation of vegetable crops in this region is possible only with irrigation. The most common irrigation methods in the Volgograd region are sprinkling and drip irrigation. However, in our opinion, subsoil irrigation (subirrigation or subsurface irrigation) can also be successfully used for growing vegetable crops in this region.

Drip irrigation is successfully used for growing vegetables and other crops in Europe (for example, in Germany [1], in France [2], in Spain [3-5]), in Africa [6-8], in Turkey [9-11], in

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China [12-17], in the USA [18-21], in Brazil [22], in India [23-24], in Canada [25] and of course in Israel [26].

The researches on the cultivation of vegetable crops at sprinkling, drip irrigation and subsoil irrigation in Volgograd State Agricultural University (Volgograd SAU) we have been conducting more than 20 years [27-34]. Their main goal is to develop a water regime for the soil to increase the yield of vegetable crops with different irrigation methods while maintaining soil fertility and environmental safety.

2 Materials and methods

The soils of the site are light brown, non-saline, medium loamy, low-humus. The humus content is no more than 1-2%. Groundwater is located at a depth of more than 3 m.

This article presents the results of research on drip irrigation (DI) of the beet in 2011-2013, of the squash - in 2012-2014, of the cabbage - in 2017-2019, as well as on subsoil irrigation (SI) of the radish - in 2015-2017.

Weather conditions during the study period were very stressful, especially in July and August. At this time, almost complete absence of rains, the highest air temperature and a large number of days with strong dry winds were observed.

Long-term researches have shown that the main component of the total water consumption of plants grown in the Volgograd region is the total consumption of irrigation water per season, that is, the volume of irrigation water. Consequently, it is possible to manage the water regime of the soil, as the main crop-forming factor, by selecting the most effective irrigation regime.

Therefore, all vegetable crops were studied with 3 options for irrigation regime on the background of 3 options for doses of mineral fertilizers and only for radish – on the background of 3 different options for the location of the irrigation network at SI.

On the experimental field with cabbage 3 variants of the drip irrigation regime were investigated: 60-70-60, 70-80-70, 80-90-80% FMC with a change of the pre-irrigation soil moisture in the interphase periods: “transplanting - the beginning of formation cabbage head”, “formation cabbage head - technical ripeness” and “technical ripeness - harvest”.

For all other crops, 3 irrigation regimes were developed: one differentiated 75-85-75% FMC and two with a constant SPIM 75 and 85% FMC.

The change of the level of soil water in the variant with a differentiated drip irrigation regime for beet occurred sequentially in the next periods “seeding - 7 leaf”, “7 leaf - closing of leaves between the rows”, “closing of leaves between the rows – harvesting; for vegetable marrow during the periods "sowing - flowering", "flowering - beginning of the fruit formation", "fruit formation - last harvest"; for radish with SI- during the periods of "seeding - beginning of the fruit formation", "fruit formation - technical ripeness", "technical ripeness - harvesting" .

In the field experiments with beet 3 variants of mineral fertilizer doses were investigated: N165P100K90, N200P120K110, N235P140K130; in the experiments with courgettes - N180P75K82, N210P87K96, N240P99K110; in the experiments with cabbage N30K1050, N70P120 kg/ha.

The second study factor in the experiments with radish were 3 variants of the location of subsoil humidifiers with a distance of 1,2; 1,4 and 1,6 m between each other.

3 Results and Discussion

The irrigation rates for vegetable crops during the period of field researches are shown in the Table 1.

Table 1. The irrigation rates for vegetable crops during the period of field researches.

SPIM, % FMC	Interphase periods		
	I	II	III
	irrigation rates, mm/ha		
Beet with DI on average for 2011-2013			
75	13.4	13.4	13.4
75-85-75	13.4	4.8	13.4
85	4.8	4.8	4.8
Courgettes with DI on average for 2012-2014			
75	10.8	10.8	10.8
75-85-75	10.8	5.4	10.8
85	5.4	5.4	5.4
Cabbage with DI on average for 2017-2019			
60-70-60	20.0	18.5	20.0
70-80-70	18.5	16.0	18.5
80-90-80	16.0	9.5	16.0
Radish with SI (for the distance between subsoil humidifiers of 1.4 m) on average for 2015-2017			
75	16.7	16.7	16.7
75-85-75	16.7	10.0	16.7
85	10.0	10.0	10.0

For subirrigation of radish in all variants of the experiment, the first watering at a rate of 5.0 mm / ha was done by sprinkling immediately after sowing for better seed germination.

The number of irrigations and volume of irrigation water for all variants of the experiments are shown in the Table 2.

Table 2. The number of irrigations and volume of irrigation water for all variants of the experiments.

SPIM, % FMC	Interphase periods			Total number of irrigations pieces	Volume of irrigation water (mm/ha)
	I	II	III		
	number of irrigations, pieces				
Beet with DI on average for 2011-2013					
75	9	17	8	34	455.6
75-85-75	9	51	8	68	472.6
85	29	52	31	112	537.6
Courgettes with DI on average for 2012-2014					
75	11	9	11	31	334.8
75-85-75	11	21	12	44	363.6
85	20	17	32	69	374.4
Cabbage with DI on average for 2017-2019					
60-70-60	4	8	4	16	308.0
70-80-70	5	10	5	20	345.0
80-90-80	7	16	6	29	360.0
Radish with SI (for the distance between subsoil humidifiers of 1.4 m) on average for 2015-2017					
75	5	10	4	18	300.0
75-85-75	3	19	5	26	317.5
85	5	20	8	33	331.6

The data obtained made it possible to establish that an increase of SPIM from 75 to 85% FMC caused a decrease of the irrigation rates for beet with DI from 13.4 to 4.8, for vegetable marrow with DI - from 10.8 to 5.4, for radish with SI- from 16.7 to 10.0mm / ha.

A similar increase of SPIM from 60-70-60 to 80-90-80% FMC in experiments with cabbage caused a decrease of the irrigation rates from 18.5 ... 20.0 to 9.5 ... 16.0 mm / ha.

At the same time, the total number of drip irrigations during the season for beet increased on average from 34 to 112, for squash- from 31 to 69, for cabbage - from 16 to 29 units, and for radish with SI- from 18 to 33 pieces. As a result, the volume of irrigation water for beet increased from 455.6 to 537.6, for squash - from 334.8 to 374.4, for cabbage - from 308.0 to 360.0, and for radish - from 300.0 to 331.6 mm / ha.

The yield of vegetable crops is shown in the Table 3.

The science researches have shown that with drip and subsurface irrigation, the main factor influencing the yield of vegetable crops was the water regime of the soil.

In experiments with beet, an increase in the intensity of the drip irrigation regime from 75 to 85% FMC against the different agronomic background caused an increase in the yield of beet from 52.5 ... 70.8 to 59.2 ... 82.4, and of squash - from 50.1 ... 63.8 to 62.0 ... 83.7 t / ha.

Table 3. Yield (Y) of vegetable crops by the options of field experiments

SPIM, % FMC	Fertilizer doses, kg/ha		
	Y, t / ha		
Beet with DI on average for 2011-2013			
	N165P100K90	N200P120K110	N235P140K130
75	52,5	61,7	70,8
75-85-75	58,4	71,7	81,1
85	59,2	73,6	82,4
Courgettes with DI on average for 2012-2014			
	N180P75K82	N210P87K96	N240P99K110
75	50,1	55,4	63,8
75-85-75	61,0	71,3	82,4
85	62,0	72,8	83,7
Cabbage with DI on average for 2017-2019			
	N70P30K100	N90P40K120	N110 P50 K140
60-70-60	48,2	54,6	61,9
70-80-70	61,4	67,3	72,2
80-90-80	71,8	78,4	83,1
Radish with SI on average for 2015-2017			
The distance between subsoil humidifiers, m			
	1,2	1,4	1,6
75	72,2	71,5	62,9
75-85-75	78,9	78,3	69,7
85	79,8	79,4	71,0

For cabbage, the rise of SPIM before drip irrigation from 60-70-60 to 70-80-70 and further to 80-90-80% FMC contributed to an increase in the yield from 48.2 ... 61.9 to 71.8 ... 93.1 t / ha.

The improvement of the water regime of soils due to an increase in SPIM from 75 to 85% FMC made it possible to raise the yield of radish from 62.9 ... 72.2 to 71.0 ... 79.8 t / ha.

The second factor affecting to the yield of vegetable crops with drip irrigation of vegetable crops was the level of mineral nutrition.

An increase in the doses of mineral fertilizers from N165P100K90 to N235P140K130, from N180P75K82 to N240P99K110, from N70P30K100 to N110P50K140 caused an increase in the yield respectively of beet from 52.5 ... 59.2 to 70.8 ... 82.4, for squash - from 50.1 ... 62.4 , 0 to 63.8 ... 83.7, for cabbage - from 48.2 ... 71.8 to 61.9 ... 83.1 t / ha

The second factor influencing to the yield of radish with SI was the location of the irrigation network. A decrease in the distance between the humidifiers from 1.6 to 1.2 m stimulated an increase in its yield from 62.9 ... 71.0 to 72.2 ... 79.8 t / ha.

4 Conclusion

Long-term researches on the cultivation of vegetable crops with different methods of irrigation in the Volgograd region have shown that their yield was primarily closely related to the improvement of the water regime of the soil. Its efficiency using drip irrigation increased with the introduction of mineral fertilizers, and using subsurface irrigation - with an improvement of the location of the irrigation network.

The highest yield of beet with drip irrigation (82.4 t / ha) was obtained with an increase of the Soil Pre-Irrigation Moisture (SPIM) to 85% of Full Moisture Capacity (FMC) and fertilization doses - to N235P140K130 kg/ha. The highest yield of squash with drip irrigation of 83.7 t / ha was obtained while maintaining the similar irrigation regime and the quantity of fertilizers N240P99K110 kg/ha. The maximum cabbage yield in our experience with drip irrigation of 83.1 t / ha was achieved using the option that combines the maintenance of the irrigation regime 80-90-80 %FMC with the application of fertilizers at doses of N110P50K140 kg / ha.

The highest yield of radish with subsurface irrigation of 79.8 t / ha was obtained while maintaining SPIM 85 % FMC in the field with the location of subsurface humidifiers at a distance of 1.2 m from each other.

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