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Improvements of the Elements of Technology of Cultivation of Watermelon in the Conditions of the Lower Volga Region

Shamil B. Bairambekov[1*], Natalya V. Tyutyuma[2], Artem S. Sokolov[3], Mikhail Y. Anishko[4]

[1*]Doctor of Agricultural Sciences, Professor, Head of the Department of Agrotechnology and Melioration, All-Russian Research Institute of Irrigated Vegetable and Melon Growing – Branch of FSBSI, "Precaspian Agrarian Federal Scientific Center of the Russian Academy of Sciences", Russia. E-mail: vniiob-100@mail.ru

[2]Doctor of Agricultural Sciences, Professor of RAS, Director, Federal State Budgetary Scientific Institution, "Precaspian Agrarian Federal Scientific Center of the Russian Academy of Sciences", Russia.
E-mail: tutumanv@list.ru

[3]Candidate of Agricultural Sciences, Senior Research Scientist, All-Russian Research Institute of Irrigated Vegetable and Melon Growing – Branch of FSBSI, "Precaspian Agrarian Federal Scientific Center of the Russian Academy of Sciences", Russia. E-mail: sspmaster@mail.ru

[4]Candidate of Agricultural Sciences, Research Scientist, Federal State Budgetary Scientific Institution, "Precaspian Agrarian Federal Scientific Center of the Russian Academy of Sciences", Russia. E-mail: amo2015@yandex.ru

ABSTRACT

The study was aimed to establish optimal nutritional areas and sowing plans for watermelon varieties with different period of ripening. Methods. During the period of vegetation of plants, the authors performed accounts and observations by generally accepted methods. Results. The weediness of crops with a stripe-cluster sowing plan and 2.1 m inter-stripe space was 2-5 times higher than in row sowing plans with 0.7 m and 1.4 m inter-row space. Nutritional areas and sowing plans influenced the dynamics of the soil moisture that was lower in dense crops and crops with stripe-cluster sowing plan. Dense planting provided plants of morphologically quick ripening types and increased photosynthetic potential of the crop. A decrease in the nutritional area in watermelon plants led to a decrease in the overall length (by 1.5-1.9 times) and the number of sprouts (by 8.0-9.9 pcs). A general decrease in the number of sprouts in dense crops occurred due to unproductive secondary sprouts. Conclusions. The study showed that the nutritional area, optimal by the general yield and economically feasible, for quick ripening variety life Photon was 0.98 м^2, for mid ripening varieties like Astrakhanskiy and late ripening varieties like Russkaya berezka – 0.98-1.96 m^2, respectively. Sowing plans for the crop had to be 1.4x0.7 m with a nutritional area of 0.98 m^2 and 1.4x1.4 m with a nutritional area of 1.96 m^2.

KEYWORDS

Water-melon, Nutritional Area, Sowing Plan, Weeds, Productivity.

Introduction

Cucurbit crops (watermelon and melon) were delivered to the Volga Region with other food commodities. This provided the development of cucurbit cultivation in the Lower Volga Region. High temperatures and favorable climatic conditions contribute to the growth of tasty and juicy cucurbit crops (Boeva 2013; Bykovskiy 2012). Presently, the issue of the provision of the Russian population with vegetables and cucurbits in the recommended amounts (125-140 kg per capita. Academy of Medical Sciences) is still acute, even though during the past decade, the average annual consumption of vegetables and cucurbits in the Russian Federation increased by 28.7% (from 87 to 112 kg) and in the Astrakhan Region – by 24.4% (from 135 to 168 kg) (Sokolov et al 2019). A great quantity of light is required for high yields of watermelons. In a dense plantstand and heavy weediness, watermelons develop poorly, their productivity and quality of products decrease (Bykovskiy and Koleboshina 2016; Sozinov 2016; Athmaselvi et al 2012; Zhang et al 2019). The study was aimed to identify the optimal nutritional area and sowing plans for the varieties of watermelon different by the habitus and the rate of ripening in the Southern Region.

Materials and Methods

Field trials were set up in the farming facilities "Bekhchintaev" (Privolzhskiy Region, Astrakhan Oblast) in 2016-2018. The soils were stream-laid meadow, average and heavy loamy, different by the mechanical composition. The content of easily hydrolyzed nitrogen (by Corkfield) was 56.7-78.1 mg/kg; labile phosphorus (by Machigin) – 37.2-64.8 mg/kg, and exchange potassium (by Machigin) – 296.3-309.7 mg/kg (Soils 1985; OST 2000). The depth of

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ground water layer was 1-2 m. The preceding crop was alfalfa. During the spring cultivation, $N_{90}P_{60}K_{60}$ mineral fertilizers were applied. The crop was planted in the II decade of May. The irrigation (8-10 during the vegetation) was performed with a frontal sprinkling machine by Bauer Linestar, the rate of irrigation varied within 250-350 m^3/ha, the irrigation norm was 3800-4000 m^3/ha, depending on the meteorological conditions. The trial plan included the following nutritional areas: 0.49; 0.98 and 1.96 m^2, and the following sowing plans: 0.7x0.7 m, 1.4x0.7 m, 1.4x1.4 m, (2.1+0.7):2x0.35 m, (2.1+0.7):2x0.7 m, and (2.1+0.7):2x1.4 m. The study of the influence of the nutritional area and sowing plan on the yield included watermelon varieties bred by VNIIOOB and selection and breeding company "Master semya". The Photon variety is quick ripening, 62-65 days, fruit with peculiar stripe pattern and reddish-pink soft flesh with high sugar content, resistant to weakly virulent anthracnose types. The Astrakhanskiy variety is mid ripening, 70-75 days, with traditional stripe pattern and soft pink flesh, resistant to weakly virulent anthracnose types. The Russkaya berezka variety is mid-late ripening, 83-88 days, the plant is abundant in vines, the fruit is wide oval with bright pink flesh, the time of storage is more than 60 days (Sokolov et al 2019). The area of the trial plot was 140-560 m^2, the record plot was 63-126 m^2; the trial replication was triple. During the period of vegetation, the authors made observations and records by the generally accepted methods: "Methods of field trials in vegetable and cucurbit farming" (Belik 1992), "Methods of counting of weeds in the South-Eastern SRAI", "Methods of field trials" (Dospekhov 1979), "Methods of field trials in vegetable farming" (Litvinov 2011; Methods of weed counting 1969). The authors accounted the density of plantstand, phenological observations after the vegetation stages, performed the evaluation of the weediness by the quantitative-weight method in a triple replication using a frame (50x50 cm, S=0.25 m^2). The accounting of the yield was performed by plots by weighting watermelons and separation them by fractions according to the standards of GOST ГОСТ 7177-2015 (GOST 2015). The dynamics of the assimilative surface was evaluated by the gravimetric method. Antecedent soil moisture was measured with an interval of 3-6 days by the thermostat-weight method. The calculation of the total water consumption of the crops was performed by the method of water balance using the equation of Kostyakov A.N. For the evaluation of the quality of the obtained products, the authors measured the sugar content and types of the contained sugars, general acidity, and ascorbic acid (Ermakov et al 1987). Mathematic processing of the obtained data was performed by the method of variance analysis by Dospekhov (1979). The studied elements of the technology were evaluated based on the performance rate and costs accepted on the farm.

Results

It is known that in dense crop, the capacity of plants to resist weeds increases and, vice versa, larger nutritional areas stimulate the development of weeds (Bairambekov 2011; Lutsenko et al 2004; Bairambekov et al 2016). This suggestion was confirmed by the results of the present study. Major vegetative mass of watermelon plants inhibited weeds. The weediness in stripe-cluster sowing plans with 2.1 m inter-stripe space was 2-5 times higher than in row sowing plans with inter-row space 0.7 and 1.4 m (Table 1). To prevent the damage of crops with stripe-cluster sowing plans, inter-row cultivations had to be stopped when vines reached 0.3-0.4 m in length. There were 12-15 days from the last inter-row cultivation to the closing of crops, which is enough for weediness in the conditions of irrigation.

Table 1. Influence of the nutritional area and sowing plan on the weediness of watermelon cultivation at the end of the vegetation period (mean for 2016-2018)

Nutritional area, m^2	Sowing plan, m	Number of weeds, pcs./m^2		
		Photon	Astrakhanskiy	Russkaya berezka
0.49	0.7x0.7	39	44	42
0.49	(2.1+0.7):2x0.35	188	192	201
0.98	1.4x0.7	110	119	127
0.98	(2.1+0.7):2x0.7	287	273	309
1.96	1.4x1.4	222	234	249
1.96	(2.1+0.7):2 x1.4	418	547	602

The nutritional area and sowing plans also influenced the dynamics of soil moisture. Despite a uniform mode of irrigation of all the variants of trials, norms, periods, and methods of irrigations, dense and stripe-cluster crops had lower moisture content. At the same time, at the beginning of vegetation, the differences between the variants were

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insignificant but increased along with the plants growth. The relative deficit of soil moisture in dense crops can be explained by the formation of abundant leaves apparatus that contributes to larger water requirements for evaporation. A decrease in the pre-irrigation soil moisture in stripe-cluster planted crops was associated with a higher level of weediness that led to more intensive water evaporation by a unit of the crop (Ovchinnikov et al 2011; Koocheki et al 2007). Watermelon plants consumed different amounts of water during different growth stages (Table 2).

Table 2. Influence of the nutritional area and sowing plan on the average daily water consumption by watermelons of the Astrakhanskiy variety (mean for 2016-2018, water-bearing layer 0.0-0.4 m)

Nutritional area, m^2	**Sowing plan, m**	**Water consumption by the phases, m^3/ha**					**Total water consumption, m3/ha**	**Water-use ratio**
		Germination – vining	**Vining – flowering**	**Flowering– 1st harvest**	**1st harvest – last harvest**	**Germination – Last harvest**		
0.49	0.7x0.7	42.6	55.4	62.3	33.7	51.2	4950	93.0
1.96	1.4x1.4	40.4	53.8	61.7	34.6	50.3	4890	111.9
1.96	(2.1x0.7):2 x1.4	41.7	54.5	62.4	33.9	50.6	4980	126.4

At the beginning of the vegetation, average daily water consumption slightly decreased. An increase in the above ground green mass and air temperature led to an increase in water consumption. Maximum daily water consumption in watermelons was observed during the period of fruit inception and formation. In the period of biological ripening of fruit, the requirements in water significantly decreased. Thus, the period of fruit inception and formation is critical in terms of water consumption. The effectiveness of agricultural technologies under irrigation is evaluated not only by the yield but also by water requirements for its operation.

Total water consumption by the Astrakhanskiy variety planted by the scheme 0.7x0.7; 1.4x1.4 and (2.1x0.7):2x1.4 m, respectively, was 4950; 4890 and 4980 m^3/ha, i.e. nearly identical. These sowing plans had water consumption coefficients 93.0; 111.9 and 126.4. Thus, the effectiveness of water use per unit of yield increased with the density of the crop and decreased when the crop was planted by the stripe-cluster pattern.

Significant damage to the yield is caused by *Orobanche aegyptiaca Pers*. (Bairambekov 2011; Sokolova et al 2014). There were records on partial and complete death of crops grown on the plots infected with *Orobanche aegyptiaca.* The observations after the land surface infested with this weed showed that it started to appear in the II decade of July – II decade of August. The most severe damage to the crop was observed in 2017 (Table 3).

Table 3. Degree of weediness with *Orobanche aegyptiaca* in the conditions of different nutritional areas of watermelons of the Astrakhanskiy variety (2017).

Nutritional area, m^2	**Sowing plan, m**	**Plantstand density, pcs./ha**	**Broomrape plants revealed on the soil surface, pcs./ha**	**Percent of weediness of watermelon plants with *Orobanche aegyptiaca***	**Quantity of *Orobanche aegyptiaca* plants per watermelon plant**
0.49	0.7x0.7	20408	14005	68.6	0.69
0.98	1.4x0.7	10204	8864	86.9	0.87
1.96	1.4x1.4	5102	6143	100.0	1.20

The obtained data showed that the lowest ratio of plants infested with *Orobanche aegyptiaca* (68.6% and 86.9%) was recorded on crops with minimal nutritional areas (0.49 and 0.98 $м^2$). The degree of harmfulness decreased with a decrease in the nutritional area. However, the absolute number of the revealed plants of *Orobanche aegyptiaca* was registered on crops with the minimal nutritional areas, especially, in cases with the sowing plan 0.7x0.7 m and 0.49 m^2 nutritional area. In the present trial, a great number of plants of *Orobanche aegyptiaca* is explained by an increased concentration of substances expressed by the roots of the host plants, which contributed to the stimulation

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of the germination of a significant number of weed seeds that were contained in the superficial layers of the soil. Presently, there are still no effective methods of eradication of *Orobanche aegyptiaca*.

Biometric measurements showed that a decrease in the nutritional area in watermelons led to significant morphological changes. On average, the general length in the Photon variety decreased by 1.9 times, Astrakhan variety – by 1.6 times, and Russkaya berezka – by 1.5 times. The number of sprouts decreased in the Photon variety by 8.0 pcs, in the Astrakhanskiy variety – by 9.1 pcs, and in the Russkaya berezka variety – by 9.9 pcs. It should be noted that a general decrease in the number of sprouts in dense crops occurred due to the appearance of unproductive secondary sprouts. Stripe-cluster sowing plan resulted in a decrease in the number and general length of all the sprouts and an increase in the number of unproductive sprouts in the Photon variety by 1.1 pcs, in the Astrakhanskiy variety – by 0.9 pcs, and in the Russkaya berezka variety – by 1.3 pcs.

During the study of the nutritional areas, it should be taken into account that the varieties different by the biology and habitus have different requirements for the optimum density of the crop which was confirmed by the present study (Boeva 2013; Sozinov 2016). In dense crop, early ripening variety Photon and mid ripening variety Astrakhanskiy had an increase in the yield along with a decrease in the studied nutritional areas, and late-ripening variety Russkaya berezka, that had abundant vegetative green mass, had a decrease in the yield in maximally dense crop (Table 4).

Table 4. Influence of the nutritional area and sowing plan on the yield of different watermelon varieties (mean for 2016-2018)

Variety (Factor A)	**Nutritional area, m^2** (Factor B)	**Sowing plan, m** (Factor C)	**Yield, t/ha**	
			Total	**Standard**
Photon	0.49	0.7 x 0.7	41.8	24.8
	0.49	(2.1+0.7):2 x 0.35	39.4	21.5
	0.98	1.4 x 0.7	37.2	31.1
	0.98	(2.1+0.7):2 x 0.7	34.5	28.1
	1.96	1.4 x 1.4	31.0	27.4
	1.96	(2.1+0.7):2 x 1.4	29.5	25.2
Astrakhanskiy	0.49	0.7 x 0.7	45.6	33.4
	0.49	(2.1+0.7):2 x 0.35	42.2	31.0
	0.98	1.4 x 0.7	45.4	37.8
	0.98	(2.1+0.7):2 x 0.7	42.4	33.3
	1.96	1.4 x 1.4	43.9	31.3
	1.96	(2.1+0.7):2 x 1.4	39.4	30.4
Russkaya berezka	0.49	0.7 x 0.7	37.2	30.2
	0.49	(2.1+0.7):2 x 0.35	33.6	27.5
	0.98	1.4 x 0.7	45.2	37.2
	0.98	(2.1+0.7):2 x 0.7	42.1	35.1
	1.96	1.4 x 1.4	45.9	37.8
	1.96	(2.1+0.7):2 x 1.4	39.3	27.2
$HCP_{0.05}$ (A)	-	-	3.9	-
$HCP_{0.05}$ (B)	-	-	4.3	-
$HCP_{0.05}$ (C)	-	-	3.1	-

All the studied varieties gave the maximal standard yield with the nutritional area of 0.98 m^2. Further thickening of the canopy led to a decrease in the standard yield. The specific weight of the yield of standard fruit in relation to the general yield was the lowest in crops with small nutritional area and high in crops with the minimum density.

In crops that form the optimal size of leaf surface, which is determined by the density, the highest quality yield of watermelons (Koleboshina et al 2010; Athmaselvi et al 2012) can be obtained using certain sowing plan and taking into account biological peculiarities of the variety (Koleboshina et al 2010; Vasilkova et al 2011). The duration of leaves lifetime and the time to the maximal leaf surface depended on the crop density. In dense crop, the leaf surface reached its maximum earlier and the withering started earlier. The observed differences in the photosynthetic activity

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between the stripe-cluster and row planted plants revealed a significant influence on the yield of watermelons. The parameters of photosynthetic activity in stripe-cluster planted crops contributed to a decrease in general and standard yield due to their increased weediness.

Depending on the nutritional area and sowing plans, the structure of the yield changed (Table 5). A decrease in the nutritional area led to an increase of non-standard (d < 0.15 m) and small (d = 0.15-0.25 m) fruit in all the studied varieties. Medium (d = 0.25-0.35 m) and large (d > 0.35 m) fruit tended to decrease in yield in dense crop.

Table 5. Influence of the nutritional area and sowing plan on the structure of yield on different watermelon variety (mean for 2016-2018)

Variety	**Nutritional area, m^2**	**Sowing plan, m**	**General yield, t/ha**					**Mean weight of standard fruit, kg**
			Total	**Including by the diameter fractures, m**				
				< 0.15	**0.15-0.25**	**0.25-0.35**	**> 0.35**	
Photon	0.49	0.7x0.7	41.8	18.0	23.6	0.2	0.0	4.37
	0.49	(2.1+0.7):2x0.35	39.4	18.7	20.5	0.2	0.0	4.33
	0.98	1.4x0.7	37.2	7.0	28.4	1.7	0.1	5.75
	0.98	(2.1+0.7):2x0.7	34.5	7.4	26.5	0.6	0.0	5.54
	1.96	1.4x1.4	31.0	4.6	24.4	1.9	0.1	6.90
	1.96	(2.1+0.7):2x1.4	29.5	4.4	23.3	1.8	0.0	5.71
Astrakhanskiy	0.49	0.7x0.7	45.6	13.3	30.4	1.7	0.2	4.67
	0.49	(2.1+0.7):2x0.35	42.2	12.7	27.7	1.6	0.2	4.38
	0.98	1.4x0.7	45.4	9.5	31.1	4.4	0.4	7.71
	0.98	(2.1+0.7):2x0.7	42.4	11.5	26.7	3.9	0.3	7.41
	1.96	1.4x1.4	43.9	4.2	29.7	9.6	0.4	7.93
	1.96	(2.1+0.7):2x1.4	39.4	6.4	28.0	4.7	0.3	7.67
Russkaya berezka	0.49	0.7x0.7	37.2	6.0	29.2	1.8	0.2	5.86
	0.49	(2.1+0.7):2x0.35	33.6	5.5	25.0	2.9	0.2	8.45
	0.98	1.4x0.7	45.4	7.8	33.4	3.8	0.4	8.69
	0.98	(2.1+0.7):2x0.7	42.1	5.4	33.8	2.6	0.3	8.35
	1.96	1.4x1.4	45.9	2.8	37.5	5.1	0.5	8.84
	1.96	(2.1+0.7):2x1.4	39.3	2.1	29.7	7.2	0.3	8.70

Stripe-cluster planted crops tended to give smaller fruit. There was an increase in the yield of non-standard fruit and a decrease in the yield of medium and large fruit. The mean mass of standard fruit sharply decreased in dense crops. In the variant with the minimal nutritional area (0.49 m^2), the fruit had thin and insufficiently firm rind. This feature was beneficial if consumed in the areas of their growth but it made the fruit unsuitable for transportation.

The study of the biochemical composition of watermelon fruit of different varieties showed that the studied elements did not influence significantly the quality of the obtained products. With some exceptions, stripe-cluster sowing plan insignificantly decreased sugar content in fruit and worsened their taste.

The economic analysis showed that in dense crops, the cost of crop growing increased primarily due to the additional expenses on additional seeds and manual weed control and harvest. As a rule, non-standard fruit (d < 0.15 m) is not sold. Thus, the comparison of different nutritional areas and sowing plans was performed by the net profit obtained from the sale of standard yield. In all the varieties, the net profit increased with a decrease in the nutritional area to 0.98 m^2. The maximal density of the crop led to a decrease in the net profit from the sale of standard products because of a higher share of non-standard fruit in the yield. In stripe-cluster planted crop, the self-cost of products increased in comparison with row-planted crops, the benefit-cost ratio and net income obtained from the selling of general and standard yield decreased.

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Conclusions

In dense crops, watermelons were formed of morphologically more early ripening types. The effectiveness of the utilization of water per yield unit increased as well as the photosynthetic potential of the crop. The area, optimal by the output of standard yield, high market quality, and economical feasibility, was 0.98 m^2 for the early ripening Photon variety and 0.98-1.96 m^2 for the mid and late-ripening Astrakhanskiy and Russkaya berezka. In crops with 0.98 m^2 nutritional area, the sowing plan should be 1.4x0.7 m, in crops with 1.96 m^2 nutritional area – 1.4x1.4 m.

Highlights

1. Weediness was evaluated in watermelon crops.
2. Average daily water consumption by watermelons was estimated.
3. The influence of the nutritional area and sowing plan on the quality of yield and fruit was studied.
4. Optimal sowing plans and nutritional areas were identified for different varieties of watermelons.
5. Technological approaches for an increase of productivity were proposed for the production.

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