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DEFFICIT IRRIGATION FOR GREEN BEANS - LATE FIELD PRODUCTION

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Abstract

The aim of this work is to establish the influence of water deficit during different vegetative stages on the yield of green beans grown at late field production. The field experiment was conducted during 2010-2012 in Agricultural University of Plovdiv. Treatments are as follows: 1) without irrigation; 2) optimum irrigation (by 80% FC for 0-40 cm soil layer); 3) without irrigation during vegetative period; 4) during budding and flowering period; 5) during the pod development period. The number of irrigations is 2-4 with amount of irrigation rate 50 mm. The yield by optimum irrigation treatment is 1609 kg/da. It is triple and more than non-irrigated (519 kg/da). The Yield losses caused of irrigation cancelling during vegetative period are 13%. More sensitive is the period of pod development with 11-33% losses. The most sensitive is budding and flowering period with average yield losses of 36% (17-58%).

Key words*: green beans, irrigation, water deficit, yield.*

INTRODUCTION

The short growing season and tolerance for abiotic factors allow green beans to be sown during the period from the second half of April to mid-July (under the conditions of Bulgaria). Thus, it is used as the main, second or an intermediate crop in crop rotations, giving high and stable yields under irrigated conditions and when applying the correct agricultural technology. The scarcity of water resources for irrigation, as well as the high cost of irrigation water, is prerequisites for the application of deficit irrigation. In practice it is usually done most often done by the cancellation of one or more irrigations. The purpose of the studies in this research direction is to determine the sensitivity to soil drought during different parts of the vegetation period on the one hand, and responsiveness to irrigation on the other (with very limited water resources). The sensitivity of green beans to drought during different periods of vegetation has been the subject of many years of research in various parts of the world. According to the publication of Poryazov (2001), green beans are very sensitive to soil and air humidity, as well as to the ambience temperature and the plant stresses caused by the fluctuation of soil moisture are reflected differently in different phenophases, as follows: water stress before flowering leads to a decrease in the number of flowers and pods, and if there is a shortage of soil water during the pod development, they remain with less weight. The author thinks that the irrigation of the beans is also a means for regulating the temperature of the crop. Oliveira, et al. (2008) found that deprivation of sufficient water during any phase of green bean vegetation results in a decrease in yield. Concerning sensitivity to soil drought, Acosta Gallegos & Shibata (1989) separate the bean vegetation period into two sub periods - vegetative and reproductive. For the Mexico conditions, cancellation of irrigation during the vegetative sub period and optimal irrigation during the reproductive sub period results in a decrease in yield of 37-39% and by irrigation through vegetative period and drought during the reproductive period, the yield decreases by 42-50%. Also comparable to these are the results published by Gunton & Evenson (1980), according to which, in Queensland (Australia), the cancellation of watering to flowering leads to a decrease in yield by 31 - 44%, and, if cancelled, irrigation during the flowering period losses are 31 - 55%. Khah et al. (2005) found that, under greenhouse conditions, cancellation of irrigation during the reproductive period of green beans leads to

significant water savings, but also to a significant decrease in yield. According to Nielsen & Nelson (1998) water stress during the vegetative phases reduces plant height and leaf area and, when apply it during the reproductive period, yield reduces due to the reduction in the number of pods per plant and their size. Nuñez-Barrios et al. (2005) also reported a significant decrease in yields following the interruption of irrigation during the reproductive period. The authors reported a 27% reduction in the number of flowers, reducing their number by twigs to 50%. Ucar et al. (2009) confirm the criticality of the period of flowering, formation and development of pods in relation to soil moisture, noting that irrigation before and after the water stress experienced by the plants during this part of the vegetation period is not able to increase the yield. Based on field experiments conducted in California (USA) Shen & Webster (1986) concludes that beans are most sensitive to soil moisture deficiency during the transition from vegetative to reproductive vegetation. Acosta Diaz et al. (1997); Albient (1976); Tawadros et al. (1983) and Calvache et al. (1997) define the flowering period as the most critical, and except that the yields at cancellation of irrigation during this phase significantly decreases and the WUE is very low. Zerbi & Chiaranda (1984) found that, for Naples (Italy), reducing the soil water potential to - 5 bars in the flowering period reduced yield by 10% and the number of beans by 30%. According to Isk et al. (2004) water stress after flowering has the most negative effect on the yield, thus the authors recommend that irrigation water be provided primarily during this part of the growing season when irrigation water is scarce.
This view is also confirmed by a publication by Ritter & Scarbrou (1992). According to the authors irrigation only during the reproductive period increases the yield by an average of 47%, compared to non-irrigated beans. Based on studies conducted in Zimbabwe, Manjeru et al. (2007) found that water stress significantly reduced bean yield, as the flowering period (duration 2 weeks from the beginning of flowering) being the most sensitive and the least sensitive to drought – vegetative period. The negative effect of water stress on the structural elements of the yield is confirmed (a significant reduction in the number of beans per bean). To obtain maximum yields, water stress during flowering and pod development should be avoided. Under non-irrigation conditions, the authors recommend sowing as early as possible. For the conditions of Bulgaria there is no information on the possibilities for applying deficit irrigation regime of the green beans by cancellation of watering. At the same time, scientists' opinions are not unidirectional in terms of phase sensitivity to drought stress. This means that studies on different soil and climatic conditions, different in character years and different (if possible contrasting in sensitivity, requirements and productivity) bean varieties are needed, to achieve a correct refinement of irrigation parameters and the possibilities for applying rational irrigation according to the specificity of the individual phenophases in terms of sensitivity to water stress.
The aim of this study is to determine the effect of cancellation of irrigation during the different phases of the growing season on the quantity and quality of yield of green beans, grown in the Plovdiv region.

MATERIALS AND METHODS

The experiment was conducted in the period 2010-2012 in the Agricultural University of Plovdiv, on alluvial-meadow soil. The *Strike* variety was used. To determine the sensitivity of green beans to drought, the growing season is separated into 3 sub periods: I period - vegetative (from germination to budding); II period - budding and flowering; III period - pod formation and development (including harvesting period). On the basis of this division of the growing season, the variants of the experiment were determined as follows: 1) without irrigation throughout the growing season (000); 2) without irrigation during the I subperiod (0++); 3) without irrigation during the II subperiod (+0+); 4) without irrigation during the III subperiod (++0); 5) optimum irrigation throughout the growing season (+++), at pre-irrigation soil moisture of 80% FC (field capacity) for the 0-40 cm layer. The irrigation rates in the optimal variant are calculated for wetting the layer 0-60 cm. The experiment was based on the block method in 4 repeats with the size of the experimental plots 18 m^2 and the harvest 10 m^2. Irrigation was done gravity by short closed furrows. The yield data and its structural components were processed by the ANOVA1 software to establish the warranty of differences between the different variants of the experiment. During the experiment, all agrotechnical activities related to the cultivation of the crop were observed.

RESULTS AND DISCUSSIONS

Meteorological conditions

Precipitations during vegetation period

The growing season in late field production of green beans concurs with the period with probability of prolonged droughts. This has been observed in all three experimental years, with a minimum precipitations amount of 36.5 mm during 2012. Although the first two years their quantity is larger (156.5 mm in 2010 and 113.3 mm in 2011), their distribution is unevenly. In 2010 the majority of the precipitations fall during the third decade of July, providing the germination of plants. In the second experimental year (2011), the peak of rainfall is at the beginning of August, as a result of which the development of plants is ensured until the flowering begins. During the critical periods in the development of the beans, namely during the flowering and pod development, the experimental years are dry.

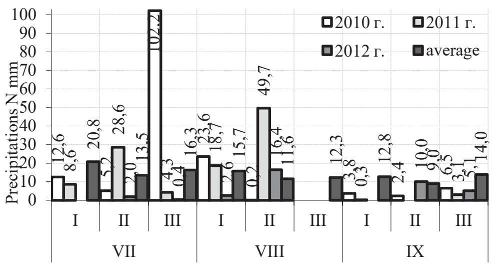

Figure 1. Precipitations amount by decades for the VII – IX period

Figure 1 shows the amount of the precipitation by decade for the period VII-IX during the three experimental years, compared with those for a multiyear period. With few exceptions, the average multiannual ten-day precipitation amounts are higher than those in the experimental years, i.e. they are drier than the norm for the area. The largest deviations from this tendency were found in the third ten days of July 2010, when the precipitation amount was 102.2 mm. They practically provide for the emergence of the plants and also store the soil with water at a greater depth than the active soil layer (0-60 cm). In the second ten days of August 2011, the rainfall is 49.7 mm, which is commensurate with the size of the irrigation rate. This results in the shift of the beginning of the irrigation period to a later phase of the growing season.

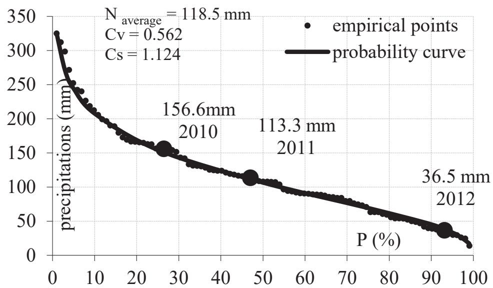

Figure 2. Precipitations probability (P) for the VII-IX period

According to the graph of Figure 2, the first (2010) year is a medium moist with a probability of 26% and the second (2011) medium with a probability of 47%. The most extreme in terms of rainfall is 2012, which is characterized as dry with 93% probability.

Air temperature

Temperature is a major factor affecting the duration of a phenophases, i.e. the duration of the all growing season (Figure 3).

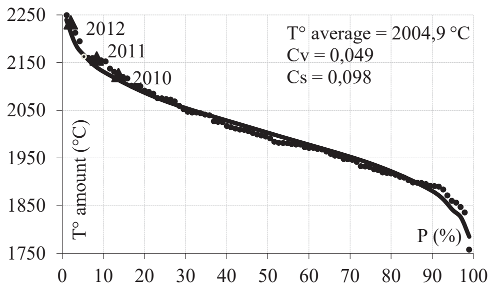

Figure 3. Probability (P) of air temperature amount for the VII-IX period

For the period July-September in the first experimental year (2010) it is 2124°C, in 2011 it is 2158°C, and in 2012 it is the highest - 2234°C. The highest is the average daily temperature in July and August and the lowest - in the period of pod development (end of September). According to the graph in Figure 3, the three experimental years are warm with a probability of 14% for 2010, 8% for 2011 and 2% for 2012, respectively. According to the meteorological characteristics, the experimental years are relatively suitable for growing of green beans.

Irrigation regime components for green beans - late field production

Data on the number of irrigations, irrigation rates and phases during which they were realized under optimal irrigation conditions are presented in Table 1. In mid-2010, a total of 3 irrigations are needed to optimize soil moisture throughout the growing season. The inter-irrigation period is 13-14 days. The irrigations are, respectively, in the phases 5-6 triple leaf, flowering and beginning of pod formation and pod development. The annual irrigation rate is 149.3 mm. The water saving is about 50 mm at practically the same irrigation rates (100 mm). During the vegetative period of the medium 2011, amount of the precipitations is sufficient to maintain optimum soil moisture. Therefore, irrigation was not carried out and this year the 0++ variant was practically not realized. Subsequently, two irrigations were applied during the inter-irrigation period again for 14 days and the irrigation rate for optimally irrigated beans 98.6 mm (Table 2).

Table 1. Number of irrigations, irrigation rates and phase of irrigation implementation under optimum irrigation conditions

№	m (mm)	Phase of the development
2010		
1	49.9	3-5 triple leaf
2	49.3	first pod set
3	50.1	pod formation and pod development
2011		
1	49.3	beginning of flowering
2	49.3	pod formation and pod development
2012		
1	53.4	3-5 triple leaf
2	57.5	budding
3	51.0	flowering
4	50.0	pod formation and pod development
m - irrigation rate (mm)		

In the +0+ and ++0 variants, irrigation was applied in the "pod development" and "flowering", respectively, so that the irrigation and irrigation rates are equal (49.3 mm). Due to the small amount of precipitations, in the dry year 2012, the number of irrigations to ensure optimal irrigation regime is 4 and the first one being during the vegetative period. During the "budding" and "flowering" period, 2 irrigations are required and the last is during the fruit development. The annual irrigation rate is 211.9 mm and 6 - 7 days period between irrigations. When thus distributed irrigations, for realizing the variants 0++ and ++0 were done three irrigations with practically uniform irrigation rates (160 mm). As the second and third irrigations are during "budding" and "flowering" for variant +0+ have been missed two irrigations, so irrigation rate is 100 mm. The irrigation regime described in this way provides a wealth of scientific information on the impact of water deficits during in different phases on the productivity of green beans - late field production.

Table 2. Irrigation regime components for green bean

date	Irrigation rates			
	+++	0++	+0+	++0
2010				
27VIII	49.9	–	49.9	49.9
09IX	49.3	49.3	–	49.3
23IX	50.1	50.1	50.1	–
M (mm)	**149.3**	**99.4**	**100.0**	**99.2**
2011				
30VIII	49.3	49.3	–	49.3
14IX	49.3	49.3	49.3	–
M (mm)	**98.6**	**98.6**	**49.3**	**49.3**
2012				
21VIII	53.4	–	53.4	53.4
29VIII	57.5	57.5	–	57.5
05IX	51.0	51.0	–	51.0
11IX	50.0	50.0	50.0	–
M (mm)	**211.9**	**158.5**	**103.4**	**161.9**
M – annual irrigation rate (mm)				
** on the day of sowing is carried watering germination rate of 20 mm*				

Influence of irrigation and cancellation of irrigation on the yield of Green Beans

Tables 3 and 4 present data on yields during different years, as well as average data on the productivity of green beans under non-irrigation conditions, optimum irrigation and phase irrigation cancellation. Optimizing soil moisture throughout the all growing season provides a statistically warranted increase in yield by about 3 times or more. It is confirmed that optimum irrigation contributes significantly to mitigating the impact of meteorological factors on the productivity of green beans. According to the summarized data, the yield increase is also more than 3 times, as under non-irrigation conditions it is 519 kg/da and under optimal irrigation - 1609 kg/da. The difference is 1090 kg/da or 310%. These results demonstrate the qualities of the variety used which and in this production direction gives an average yield under non-irrigated conditions of nearly 520 kg/da or 32% of the maximum.

Table 3. Irrigation regime influence on the yield

variant	yield kg/da	to 000			to +++		
		±Y	%	w	±Y	%	w
2010							
000	524.0	St.	100.0	St.	-951.6	35.5	C
+++	1475.6	951.6	281.6	C	St.	100.0	St.
0 + +	1028.2	504.2	196.2	C	-447.4	69.7	C
+0+	1226.0	702.0	234.0	C	-249.6	83.1	B
++0	1305.6	781.6	249.2	C	-170.0	88.5	A
GD (kg/da) 5% = 160.5 1% = 221.1 0.1% = 303.9							
2011							
000	356.1	St.	100.0	St.	-981.0	26.6	C
+++	1337.1	981.0	375.5	C	St.	100.0	St.
0++	1328.3	972.2	373.0	C	-8.8	99.3	n.s.
+0+	562.3	206.2	157.9	C	-774.8	42.1	C
++0	895.5	539.4	251.5	C	-441.6	67.0	C
GD (kg/da) 5% = 105.3 1% = 145.1 0.1% = 199.5							
2012							
000	676.3	St.	100.0	St.	-1338.5	33.6	C
+++	2014.8	1338.5	297.9	C	St.	100.0	St.
0++	1826.7	1150.4	270.1	C	-188.1	90.7	n.s.
+0+	1297.4	621.1	191.8	C	-717.4	64.4	C
++0	1368.8	692.5	202.4	C	-646.0	67.9	C
GD (kg/da) 5% = 227.9 1% = 314.0 0.1% = 431.7							
W - warranty							

Table 4. Irrigation regime influence on the yield - average

Var.	yield kg/da	to 000		to +++	
		±Y	%	±Y	%
000	518.8	St.	100.0	-1090.4	32.2
+++	1609.2	1090.4	310.2	St.	100.0
0++	1394.4	875.6	268.8	-214.8	86.7
+0+	1028.6	509.8	198.3	-580.6	63.9
++0	1190.0	671.2	229.4	-419.2	73.9

Drought during early vegetation periods adversely affects the yield due to the inhibition of growth and the development of sufficient photosynthetic leaf area. However, subsequent optimization of soil moisture ensures that approximately 90% of the maximum yield is obtained for the specific conditions. The cancellation of watering in the third period of vegetation has a more pronounced negative effect on the yield, in the middle of the wet years it reaches almost 90% of the maximum, but in the average dry and dry years - it is only 70% (67-68%). In confirmation of the results published by a number of authors, drought during the flowering period is most critical in terms of yield. Although this period has a short duration, cancellation of irrigation results in the most significant decrease in yield. In favorable years it reaches just over 80% of the maximum, but in average dry and dry years it may not reach even up to 50% of it (42-64%).

Providing irrigation only during the reproductive period increases yields by at least twice, and in dry years this increase can reach and exceed 300%. In more favorable from a meteorological standpoint years, irrigation during the reproductive period and the period of pod development can increase yields by over two times, but in dry years this increase is relatively small (below 60%), considering results under non-irrigation conditions. While maintaining the soil moisture in the optimum range of the beginning of the vegetation until the end of flowering, the yield increased by 230% compared to that in non-irrigated conditions. Regardless of the conditions of the year, this increase is at least 200% (202-252%).

Irrigation water use efficiency (IWUE) and yield losses

The results of the yield losses resulting from the cancellation of irrigation, as well as the additional yield of each 1 m^3 of irrigation water, depending on the conditions of the year, are presented in Table 5. The cancellation of irrigation during the growing season, combined with prolonged drought, can lead to a significant loss of yield (up to 30%). In the presence of rainfall and shortening of the deficit period, the cancellation of this irrigation has a less pronounced negative effect on the yield, with losses between 1 and 9%. In meteorological-favorable years, the negative effect on yield of irrigation cancellation during flowering is expressed by a yield loss of 17%. However, if there is no rainfall and no irrigation during this period, the losses are significant and are in the range of 36-58%. A less pronounced negative effect is observed in the cancellation of watering during the period of pod development and harvests. In years where there is also rainfall, losses from unrealized irrigation are just over 10%, and in years with significant drought, they are also significant (32-33%). In conclusion it can be said that irrigation cancellation during the growing season results in the lowest yield losses, followed by cancellation during the pod development and harvest period, and the largest are irrigation cancellation losses during the period of budding and flowering, which is actually the shortest as duration.

Table 5. Irrigation water use efficiency (IWUE) and yield losses

variant	Additional yield	Yield losses		M	IWUE
	kg/da	kg/da	%	mm	kg/m^3
2010					
000	St.	-951.6	-64.5	0.0	–
+++	951.6	St.	St.	149.3	6.374
0++	504.2	-447.4	-30.3	99.4	5.072
+0+	702.0	-249.6	-16.9	100.0	7.020
++0	781.6	-170.0	-11.5	99.2	7.879
2011					
000	St.	-981.0	-73.4	0.0	–
+++	981.0	St.	St.	98.6	9.949
0++	972.2	-8.8	-0.7	98.6	9.860
+0+	206.2	-774.8	-57.9	49.3	4.183
++0	539.4	-441.6	-33.0	49.3	10.941
2012					
000	St.	-1338.5	-66.4	0.0	–
+++	1338.5	St.	St.	211.9	6.317
0++	1150.4	-188.1	-9.3	158.5	7.258
+0+	621.1	-717.4	-35.6	103.4	6.007
++0	692.5	-646.0	-32.1	161.9	4.277
average					
000	St.	-1090.4	-67.8	0.0	–
+++	1090.4	St.	St.	153.3	7.114
0++	875.6	-214.8	-13.3	118.8	7.368
+0+	509.8	-580.6	-36.1	84.2	6.052
++0	671.2	-419.2	-26.1	103.5	6.487
*M - annual irrigation pate					

The IWUE is related to the influence of the period with water reduction and in combination, the favorable situation after the cancellation of the irrigation within the respective period is reflected. These circumstances are due to variations in values for a given irrigation regime over different meteorological conditions. With optimal irrigation, the impact of the year is the least pronounced. The indicators for applying the 0++ variant are high and stable, which is also in sync with the data on yields and losses. This irrigation regime also gives the highest averages. The cancellation of irrigation through flowering significantly reduces the value of the IWUE.

Influence of irrigation regime on the quality of production

Tables 6, 7 and 8, as well as Figures 4, 5 and 6 present the results concerning some structural elements of the yield, such as the mass of one bean, the length and diameter of the beans.

Table 6. Influence of irrigation regime on the beans weight

variant	g	to 000			to +++		
		±Y	%	W	±Y	%	W
2010							
000	3.8	St.	100.0	St.	-1.1	77.6	C
+++	4.9	1.1	128.9	C	St.	100.0	St.
0++	4.3	0.5	113.2	B	-0.6	87.8	C
+0+	4.4	0.6	115.8	C	-0.5	89.8	B
++0	4.9	1.1	128.9	C	0.0	100.0	n.s
GD (g): 5% = 0.3 1% = 0.4 0.1% = 0.5							
2011							
000	3.1	St.	100.0	St.	-1.4	68.9	C
+++	4.5	1.4	145.2	C	St.	100.0	St.
0++	4.4	1.3	141.9	C	-0.1	97.8	n.s.
+0+	3.5	0.4	112.9	A	-1.0	77.8	C
++0	4.2	1.1	135.5	C	-0.3	93.3	n.s.
GD (g): 5% = 0.3 1% = 0.4 0.1% = 0.5							
2012							
000	4.3	St.	100.0	St.	-1.0	81.1	C
+++	5.3	1.0	123.3	C	0.0	100.0	St.
0++	4.6	0.3	107.0	n.s.	-0.7	86.8	B
+0+	4.6	0.3	107.0	n.s.	-0.7	86.8	B
++0	4.9	0.6	114.0	A	-0.4	92.5	n.s.
GD (g): 5% = 0.4 1% = 0.6 0,1% = 0.8							
W - warranty							

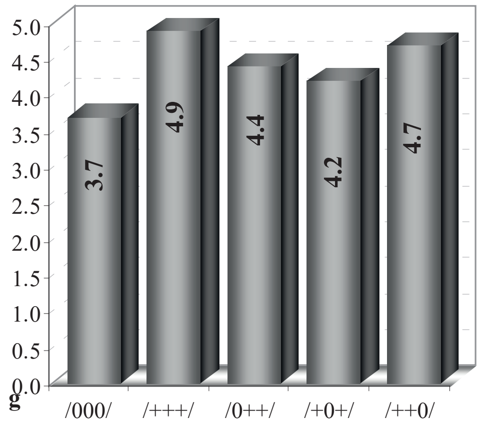

Figure 4. Influence of irrigation regime on the beans weight (average)

Under non-irrigation conditions, the mass of the beans is 3.7 g (3.1 to 4.3 g) and they are on average 1.2 g lighter than those under optimum irrigation. This difference is warranted statistically, regardless of the conditions of the year. During dry years, the cancellation of irrigation during the vegetative period or during flowering leads to weight of beans close to those under non-irrigation conditions, even though the necessary irrigations were made during the period of formation and development of the beans. The difference in weight of beans against optimum irrigation is significant and statistically warranted, regardless of the conditions of the year. In more favorable years it is 10% and in the case of drought it reaches 22% (average 15%).

Irrigation affects the length of the pods of beans, regardless of the conditions of the year, but it is less than the impact on the mass of pods. The best results are obtained with optimum irrigation (14.1 cm), which corresponds to the specified characteristics variety. The increase in the length of the beans compared to those under non-irrigation conditions was 2.1 cm or 15%, and this increase was statistically warranted (Table 7).

Table 7. Influence of irrigation regime on the beans length

variant	cm	to 000			to +++		
		±Y	%	w	±Y	%	w
2010							
000	12.3	St.	100.0	St.	-1.7	87.9	C
+++	14.0	1.7	113.8	C	St.	100.0	St.
0++	12.9	0.6	104.9	A	-1.1	92.1	C
+0+	13.0	0.7	105.7	A	-1.0	92.9	C
++0	13.5	1.2	109.8	C	-0.5	96.4	n.s.
GD: 5% = 0.5 cm 1% = 0.7 cm 0.1% = 0.9 cm							
2011							
000	11.8	St.	100.0	St.	-1.9	86.1	C
+++	13.7	1.9	116.1	C	St.	100.0	St.
0++	13.5	1.7	114.4	C	-0.2	98.5	n.s.
+0+	11.9	0.1	100.8	n.s.	-1.8	86.9	C
++0	12.5	0.7	105.9	C	-1.2	91.2	C
GD: 5% = 0.3 cm 1% = 0.4 cm 0.1% = 0.6 cm							
2012							
000	11.9	St.	100.0	St.	-2.7	81.5	C
+++	14.6	2.7	122.7	C	St.	100.0	St.
0++	12.8	0.9	107.6	A	-1.8	87.7	C
+0+	13.5	1.6	113.4	C	-1.1	92.5	B
++0	14.0	2.1	117.6	C	-0.6	95.9	n.s.
GD (cm): 5% = 0.7 1% = 0.9 0.1% = 1.3							
W - warranty							

The most pronounced negative effect on the length of the beans is observed when the irrigation is cancelled during flowering, resulting in the length of the beans reaching between 87 and 93% of the maximum. When the irrigation is cancelled during the vegetative period, the beans reach an average of 93% of the maximum length, but in favorable years it is commensurate with that of optimal irrigation. However, in dry years the difference is significant - over 12%. The length of the beans is least affected by the meteorological conditions of the year when the irrigation is cancelled during the third period, resulting in 91-96% of the maximum length.

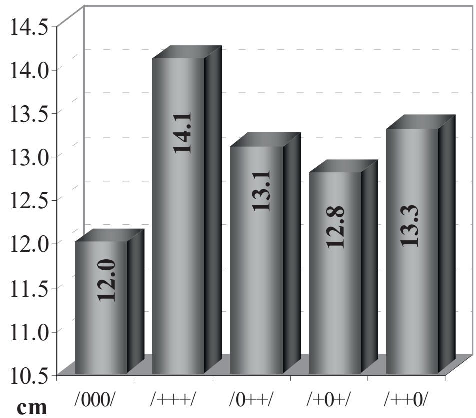

Figure 5. Influence of irrigation regime on the beans length (average)

Table 8. Influence of irrigation regime on the beans diameter

variant	mm	to 000			to +++		
		±Y	%	w	±Y	%	w
2010							
000	7.8	St.	100.0	St.	-0.4	95.1	C
+++	8.2	0.4	105.1	C	St.	100.0	St.
0++	7.8	0.0	100.0	n.s.	-0.4	95.1	C
+0+	7.8	0.0	100.0	n.s.	-0.4	95.1	C
++0	7.8	0.0	100.0	n.s.	-0.4	95.1	C
GD (mm): 5% = 0.1 1% = 0.2 0.1% = 0.3							
2011							
000	8.1	St.	100.0	St.	-0.5	94.2	C
+++	8.6	0.5	106.2	C	St.	100.0	St.
0++	8.6	0.5	106.2	C	0.0	100.0	n.s.
+0+	8.2	0.1	101.2	n.s.	-0.4	95.3	C
++0	8.4	0.3	103.7	B	-0.2	97.7	A
GD (mm): 5%=0.1 1%= 0.2 0.1% =0.3							
2012							
000	7.9	St.	100.0	St.	-0.9	89.8	C
+++	8.8	0.9	111.4	C	St.	100.0	St.
0++	8.1	0.2	102.5	n.s.	-0.7	92.0	C
+0+	8.3	0.4	105.1	A	-0.5	94.3	B
++0	8.6	0.7	108.9	C	-0.2	97.7	n.s.
GD (mm): 5% = 0.3 1% = 0.4 0.1% = 0.6							
W - warranty							

Regarding the diameter of the beans, the trend of the previous two indicators is maintained, but the overall impact of both irrigation and drought is even less pronounced. The averaged data show that under optimal irrigation, the bean diameter is 8.5 mm and is 0.6 mm larger than that under non-irrigation conditions (Table 8). The cancellation of watering slightly changes the diameter of the beans within about 5%, but this relative decrease is statistically warranted.

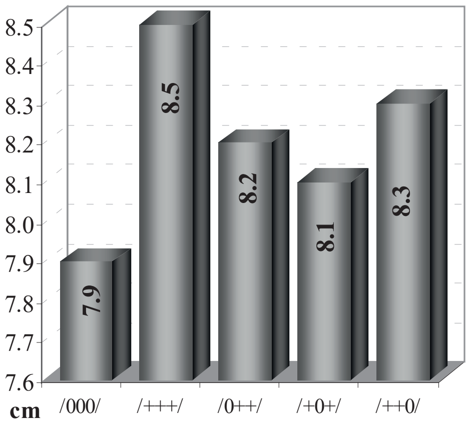

Figure 6. Influence of irrigation regime on the beans diameter (average)

Figure 6 summarizes data on the influence of irrigation regime on the diameter of the beans. With regard to irrigation cancellation options, the most significant relative decrease in this indicator value was in the case of cancellation during flowering (5%). Under non-irrigation conditions, it is 7%, and under the variants 0++ and ++0 - respectively 4 and 3%.

CONCLUSIONS

To optimize soil moisture, for green bean late production, it is necessary to supply 2-4 irrigations with an irrigation rate of 50 mm, with a maximum of 1irrigation during the vegetative period and 1-2 during flowering. During the development of beans and harvests, it is usually given 1 irrigation, and in dry years - 2.

Regardless of which phase is irrigation cancelled, this has a negative effect on the rate of linear growth, as drought during flowering having the most pronounced negative impact, and subsequent optimization of soil moisture cannot compensate for this lag.

Drought during early vegetation periods adversely affects yields, but with subsequent optimization of soil moisture, yields are around and above 90% of the maximum yield for the specific conditions. The cancellation of irrigation in the third period of vegetation has a more pronounced negative effect on the yield, in the mid-wet years it reaches almost 90% of the maximum, but in the average dry and dry years - it is only 70%. The cancellation of irrigation through flowering leads to the most significant decrease in yield. In favorable years it reaches just over 80% of the maximum, but in average dry and dry years it may not reach even up to 50% of it (42-64%).

The irrigation water use efficiency is highest when irrigation is cancelled during the vegetative period. The values of the indicator at optimum irrigation vary the least. The cancellation of irrigations during flowering most significantly reduces the values of the indicator.

With enough water for irrigation, it is best to apply a biologically optimal irrigation regime as it coincides with the economically optimal one. In case of shortage of irrigation water, it should to apply rational irrigation regime, recommending cancellation of irrigation during the vegetative period. The cancellation of irrigation during the reproductive period significantly worsens economic performance, especially if it occurs during the flowering period.

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