

*\*E-mail: sa6\_m@abv.bg*

## **PHOTOSYNTHETIC POTENTIAL OF GARDEN BEAN IN IRRIGATION WITH OPTIMUM AND REDUCED IRRIGATION RATES**

Radost Kalaydjieva, Velika Kuneva, Alexander Matev\*,  
Zlatko Zlatev

*Agricultural University, Plovdiv, Bulgaria*

### **SUMMARY**

The aim of the study is to determine the influence of irrigation regime on the values of photosynthetic potential in garden bean. Data from field experiments conducted in the experimental station of Agricultural University-Plovdiv during the period 2010-2012 year were used. The study on photosynthetic potential is done in optimal irrigation and irrigation with reduced watering rates, as well as non-irrigated conditions. Values for photosynthetic potential are established in dynamics, in aggregate and sub-periods, as it is derived linear dependence on yield. Through this dependence the photosynthetic potential can be predicted before the end of the vegetation.

**Key words:** garden beans, irrigation regime, photosynthetic potential, yield

Abbreviation: CPP – crop photosynthetic potential; FC – field capacity; LA – leaf area

2010-2012

## INTRODUCTION

The role of leaves as assimilating organs is crucial, since 90-95% of the biological production of plants is created in the process of photosynthesis (Nikolov, 1973).

The amount of leaf area, the speed of its formation and duration of work has a significant impact on the quantity of biological and economic yield (Chervenkova et al., 2007; Georgiev, 1998).

Complete picture of the magnitude of the leaf photosynthetic apparatus and duration of its assimilation activity gives so called crop photosynthetic potential (CPP). Nichiporovich (1961, 1982) proposes that it be taken into account in leaf-days thousand square meters per hectare (ha), as the sum of the daily values of leaf area per hectare (acre).

For the conditions of Bulgaria, studies on the impact of irrigation regime on the values of this indicator are made by Nikolov (1973, 1974) for maize and cotton, and for sugar beet by Matev et al. (2007).

The aim of this study was to investigate the influence of optimal irrigation and application of regulated water deficiency (by irrigation with reduced watering rates) on the values of crop photosynthetic potential (CPP) in garden bean.

## MATERIAL AND METHODS

The experiments were performed in the period of 2010-2012 year in the experimental field of AU-Plovdiv on alluvial soil. The variants of the experiment were as follows: 1) the optimum irrigation scheme 80-80-80% of the Field Water Capacity (FWC); 2) irrigation with 30% reduction of irrigation rates (70% m); 3) irrigation with 70% reduction of irrigation rates (30% m); 4) without irrigation. Irrigations in variants 1, 2 and 3 were submitted simultaneously, as it is observed corresponding adjustment of the irrigation norms.

Irrigation is carried out by gravity along furrows, and irrigation norms were done to wetting the soil to a depth of 60 cm. Crop photosynthetic potential (CPP) was calculated as the sum of the leaf area of crop for each day of the growing season (Nichiporovich 1961, 1963, 1982). Following formula was used:

$$FSP = \frac{LA_1 + LA_2}{2} \cdot N \quad [m^2 \text{ leaf-days}^{-1} \text{ ha}^{-1}] \quad (1)$$

$$CPP = \frac{LA_1 + LA_2}{2} \cdot N \quad [m^2 \text{ leaf-days}^{-1} \text{ ha}^{-1}]$$

where: CPP is crop photosynthetic potential;  $LA_1$  and  $LA_2$  is the leaf area at the beginning and at the end of the reporting period;

; N –  
 .  
 10  
 -  
 -  
 .

N – duration of time period in days.

- Leaf area is detected by scanning the 10 plants using specialized computer program.

## RESULTS AND DISCUSSION

The experiment includes  
 - three disparate in meteorological terms of years. This resulted in significantly affected CPP in variants and years.

In this connection it is made  
 - statistical evaluation of  
 - experimental years in terms of  
 - rainfall and temperature sum for  
 - May-July period, using data for  
 - multiple years (Table 1).

( 1).

1.

V-VII

**Table 1. Meteorological factors for V-VII period for region of Plovdiv**

/factor		101 average for 101 years	2010	2011	2012
N	mm	170.2 mm	197.8	96.9	205.6
	P %		24.8	89.2	23.5
T°	°C	1910°C	1960	1993	2089
	P %		30.4	21.6	4.9
* N – /precipitations; T° – /temperature; P% – /probability					

24.8%  
mm.

197.8

“ ”.

100 mm

The first experimental year was average wet with security of 24.8% and rainfall of 197.8 mm, and this provide the plant growth to phase "budding."

- During flowering and initial formation of pods, rainfall is slight, but fallen more than 100 mm rainfall at harvest period are

without agronomic importance.

Similar is the distribution of vegetation rainfall in 2011, when over 50% of it falls to the beginning of the reproductive period. During flowering there is drought, and rain fallen at the end of vegetation of about 40 mm are also ineffective.

This year was characterized as dry, with 89.2 % certainty. The third experimental year (2012) is a medium wet with 23.5% certainty, but 98% of the precipitation are falling in the initial stage of development of culture and it maintain soil moisture at an optimum stage to phase "budding".

The sum of daily average air temperature for the period May-July in the first experimental year is 1960 °C, in the second – 1993°C, and the third experimental year it is 2089 °C. Probability is 30.4%, 21.6% and 4.9%, respectively, i.e. the first two years are on average warm, and the third one is hot.

without agronomic importance.

Similar is the distribution of vegetation rainfall in 2011, when over 50% of it falls to the beginning of the reproductive period. During flowering there is drought, and rain fallen at the end of vegetation of about 40 mm are also ineffective.

This year was characterized as dry, with 89.2 % certainty. The third experimental year (2012) is a medium wet with 23.5% certainty, but 98% of the precipitation are falling in the initial stage of development of culture and it maintain soil moisture at an optimum stage to phase "budding".

The sum of daily average air temperature for the period May-July in the first experimental year is 1960 °C, in the second – 1993°C, and the third experimental year it is 2089 °C. Probability is 30.4%, 21.6% and 4.9%, respectively, i.e. the first two years are on average warm, and the third one is hot.

*Dynamics of formation of CPP*

Irrigation regime substantially affect the amount of leaf area in bean, and this effect is presented during the three experimental years – quite different in meteorological terms. Since photosynthetic potential is determined based on the values of leaf area and it should also be influenced by the degree of water

availability of plants.

Its formation depending on the applied irrigation regime is presented visually (in years) in Figures 1, 2 and 3. The reduction of irrigation norms compared to optimal variant (variant 1) has a negative impact on the development of the leaf apparatus.

Besides the amount of irrigated norms, influence of the character of the year is very well shown.

Timely submission of irrigations, even at reduced rates, is extremely important condition for the normal growth rate of leaf area.

1, 2 3. ( )  
( 1)

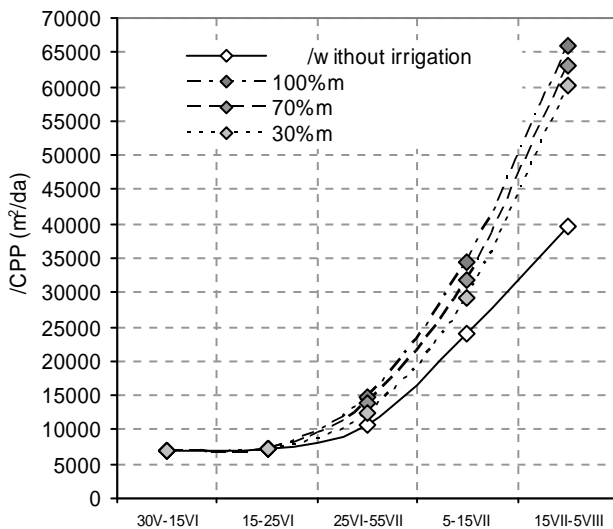
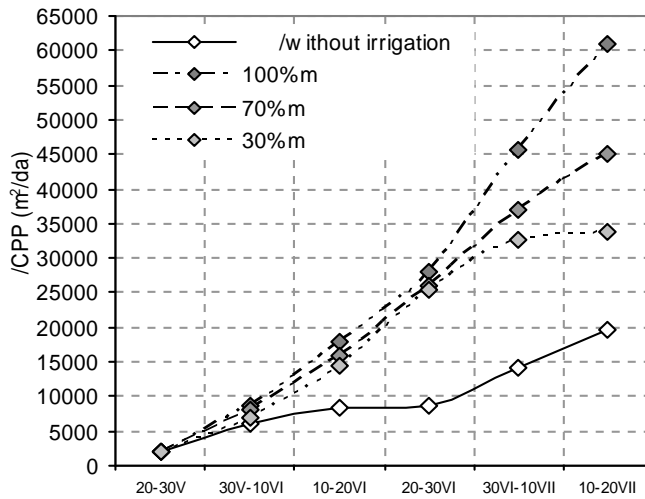
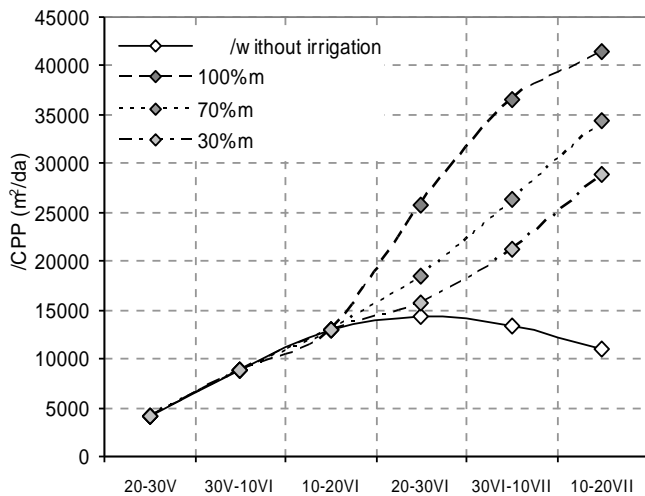


Fig. 1. CPP formation during 2010

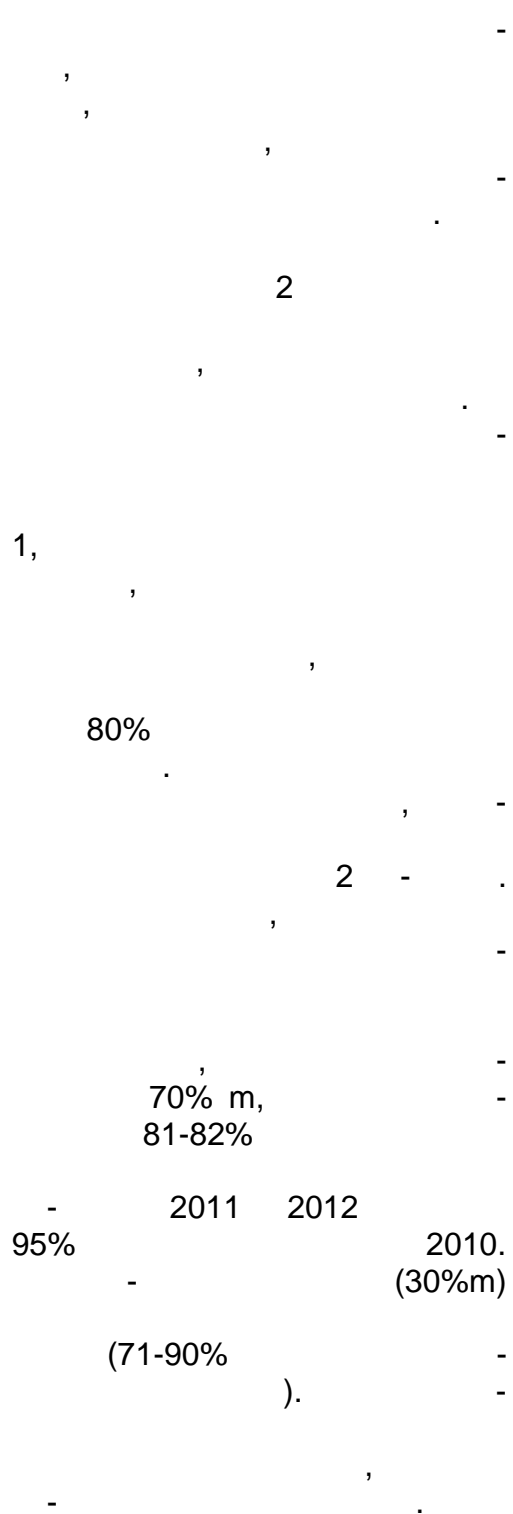


. 2. **2011**  
**Fig. 2. CPP formation during 2011**



. 3. **2012**  
**Fig. 3. CPP formation during 2012**

During the three experimental years regular irrigation even with the smallest norm (30% m), provide significantly higher values of CPP, compared to that in non-irrigated bean. Differences between irrigated variants are dictated by the different water



- deficit accumulated in the active soil layer, due to reduced irrigation norms and their amount is mainly the result of the length of the drought.

*Cumulative CPP*

In Table 2 cumulative values of CPP in variants, in years, and average of experimental period are shown. In three experimental years the highest aggregated values of CPP are established Variant 1, which conclusively show that for the normal development of leaves of Green Beans, soil moisture should not fall below 80% of FC throughout the growing season.

Compared with non-irrigated beans, average CPP of this variant for the three years is twice larger.

In variants irrigated with reduced rates, aggregate values CPP are fully in line with the climate conditions of the year. When realizing 70% m, the same values are to 81-82% of that obtained in optimum irrigation in the drier 2011 and 2012 years, and these values reached 95% during favorable 2010.

In the smaller rate (30% m) CPP is also relatively high (71-90% of that for optimal irrigation). These results are due to the regular submission of irrigations, although smaller irrigation norms.



2.

**Table 2. Total CPP of French bean by variants, years and average for all vegetation period**

variant	CPP m <sup>2</sup> /da	4		1		CPP m <sup>2</sup> /da	4		1		
		±	%	±	%		±	%			
		2010 (57 /days)					2011 (61 /days)				
1	129051	40482	145.7	St.	100.0	163419	104475	277.2	St.	100.0	
2	122905	34336	138.8	-	6146	95.2	134365	75420	228.0	-29055	82.2
3	116062	27493	131.0	-	12989	89.9	115759	56815	196.4	-47660	70.8
4	88570	St.	100.0	-	40482	68.6	58944	St.	100.0	-104475	36.1
		2012 (61 /days)					/average 2010-2012 (60 /days)				
1	129611	64944	200.4	St.	100.0	140694	69967	198.9	St.	100.0	
2	105365	40698	162.9	-	24246	81.3	120878	50151	170.9	-19816	85.9
3	91805	27138	142.0	-	37806	70.8	107875	37149	152.5	-32818	76.7
4	64667	St.	100.0	-	64944	49.9	70727	St.	100.0	-69967	50.3

*Formation of CPP in periods*

- Photosynthetic potential of  
 - beans is established aggregate  
 - and in periods as follows: I period -  
 - to budding; II period - from  
 - budding to the first fruit set; III  
 - period - from first fruit set until the  
 - end of the harvesting period.

- In Table 3 data in variants for  
 - total CPP by periods of three  
 - years and average CPP are  
 - presents. During the vegetative  
 - growth, which has the longest  
 - duration, the absolute value of the  
 - CPP at the different variants  
 - depend on whether there are  
 - realized irrigations because in this  
 - part of vegetation water  
 - consumption is still low and the  
 - available soil moisture largely  
 - secured plants.

- An indication of this situation was  
 - 2012, when during the first  
 - vegetative period no irrigations  
 - have been made. During the first

two experimental years one watering is realized up to budding period and depending on water availability different values of CPP are established.

12 (10-), The second period is very short (10-12 days), but it requires the implementation minimum of a watering. In the third period, when leaf area reached maximum values in extreme meteorological factors irrigation regime is most intense.

- In terms of absolute CPP, the trends identified in the cumulative CPP were retained in the individual sub-periods, and with vegetation progress the differences between the variants are increase.

2010 - During the more favorable 2010, in all variants relative CPP formed in the first period is the smallest (12-18% and average LA for 1 day of 340-360 m<sup>2</sup>/da).

1 (12-18% 340-360m<sup>2</sup>/da).

4 - During the second experimental year in variant 4 more intensive formation of LA in the first period compared to the second is observed, which results in greater CPP (24.0%). The main reason for this is lower cumulative values of CPP for this variant, resulting in impaired formation of LA during reproductive period.

(24.0%).

283  
469 m<sup>2</sup>/da

1.

-  
4

Average LA per day increased from 283 m<sup>2</sup>/da in variant 4 to 469 m<sup>2</sup>/da in variant 1. With reduction of irrigation norms, values of LA gradually decreased.

3.

**Table 3 Formation of CPP in the different periods**

year	variant	period		I period		II period		total	
		m <sup>2</sup> /da	%	m <sup>2</sup> /da	%	m <sup>2</sup> /da	%	m <sup>2</sup> /da	%
2010	1	17102	13.3	25500	19.8	86449	67.0	129051	100.0
	2	16952	13.8	23858	19.4	82095	66.8	122905	100.0
	3	16677	14.4	21765	18.8	77620	66.9	116062	100.0
	4	16308	18.4	18137	20.5	54125	61.1	88570	100.0
2011	1	23469	14.4	33470	20.5	106480	65.2	163419	100.0
	2	21544	16.0	30846	23.0	81974	61.0	134365	100.0
	3	19369	16.7	29820	25.8	66570	57.5	115759	100.0
	4	14128	24.0	11076	18.8	33740	57.2	58944	100.0
2012	1	23367	18.0	23158	17.9	83086	64.1	129611	100.0
	2	23367	22.2	17432	16.5	64566	61.3	105365	100.0
	3	23367	25.5	15104	16.5	53334	58.1	91805	100.0
	4	23367	36.1	14067	21.8	27233	42.1	64667	100.0
average	1	21313	15.1	27376	19.5	92005	65.4	140694	100.0
	2	20621	17.1	24046	19.9	76212	63.0	120878	100.0
	3	19804	18.4	22230	20.6	65841	61.0	107875	100.0
	4	17934	25.4	14427	20.4	38366	54.2	70727	100.0

2012

- During the extreme 2012 first period passes in a favorable natural soil water conditions, that is why CPP in variants do not differ significantly. Daily average LA is 630-720 m<sup>2</sup>/da (Table 4).

720m<sup>2</sup>/da (

4).

630-

- The relative values of CPP for this period differ significantly due to the abrupt change of environmental conditions over the next two periods and applied irrigation

regime.

- By improving water availability to the plants these differences
- decreased due to significant
- increase in the absolute cumulative values.

4.

**Table 4. Daily values of CPP in the different periods**

variant	Periods			average	Periods			average
	m <sup>2</sup> /da	m <sup>2</sup> /da	m <sup>2</sup> /da		m <sup>2</sup> /da	m <sup>2</sup> /da	m <sup>2</sup> /da	
	2010				2011			
1	356	2125	3325	1501	469	2789	5324	1993
2	353	1988	3158	1429	431	2571	4099	1639
3	347	1814	2985	1350	387	2485	3329	1412
4	340	1511	2082	1030	283	923	1687	719
2012				/average 2010-2012				
1	632	2316	4887	2025	474	2489	4381	1827
2	632	1743	3798	1646	458	2186	3629	1570
3	632	1510	3137	1434	440	2021	3135	1401
4	632	1407	1602	1010	399	1312	1827	919

4,

A significant percentage of CPP is formed during the second period for variant 4 as this is at the expense of CPP during the third period. Generally the differences between the variants in this part of the vegetation are not very big, mainly because of its low duration.

The relative values of CPP during this short period are indicative for the intensity of the formation of leaf apparatus in beans and absolute values reflect the effects of applied irrigation regime (total for the first and the second period) and weather conditions.

- Average for the three experimental

( - 1/5 )  
 1000 3000 m<sup>2</sup>/da  
 67% 2/3  
 ( 3325 5324 m<sup>2</sup>/da )

years during the second period (budding – the first fruit set) about 1/5 of the cumulative CPP of Green Bean is formed. In this part of the vegetation of bean mean LA per day varies widely – from 1000 to 3000 m<sup>2</sup>/da and as can be seen from the table, the impact of the irrigation system is very strong, while the influence of the growing conditions during the previous period is maintaining.

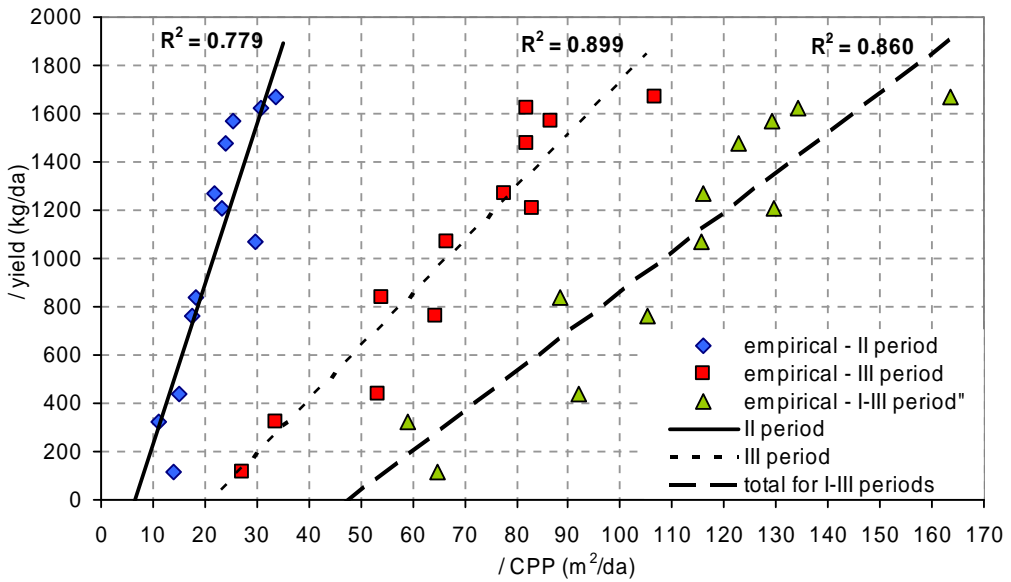
The intensity of accumulation of leaf area and leaf mass during the third sub period continued to grow in all variants and years, and held the largest relative ratio in the cumulative CPP. Maintaining optimal water-air regime in the active soil layer of bean crop in this part of the vegetation equalizes the relative values of this parameter, regardless of the nature of the year.

64- These are in the range from 64% to 67% at optimum irrigation, i.e. about 2/3 of the CPP is formed during the formation and growth of the pods for optimal irrigated garden bean. The advantage of this variant is significant with regard to the average daily values of LA – 4381 m<sup>2</sup>/da (from 3325 to 5324 m<sup>2</sup>/da).

In the variants with reduced irrigated rates the positive impact of regular waterings again stands out. In the third period of

70% m, 2012, 58 61%).

vegetation, in the wetland 2010 year, CPP is the same at the rates of 30 to 70% m, and during the dry 2011 and 2012 years, the relative values of the corresponding variants are also similar (58 and 61% respectively).



. 4.

**Fig. 4. Relationship “Yield-CPP” for different periods and total for all vegetation period**

There is a close correlation between yield and crop photosynthetic potential established for different periods and for the entire growing season. The same is presented graphically in Figure 4 and the parameters of the relationship are reflected in Table 5. The data for absolute yield and the corresponding CPP for the four variants are used. The information on the first period is missing, as there is no correlation between

, " " -  
 , .  
 ,  
 ,  
 ,  
 .  
 R<sup>2</sup>=0.779.  
 ,  
 , 6573  
 m<sup>2</sup>/da,  
 1000 kg/da – 21725 m<sup>2</sup>/da.  
 -  
 ,  
 ,  
 .  
 , R<sup>2</sup>.  
 ,  
 R<sup>2</sup>=0.899. -  
 -

CPP reported to phase "budding" and the final yield. This is because in this part of the vegetation of bean needing of watering are rear or, if necessary, the irrigations typically implemented at the end of the period.

As a result, CPP does not change or changes a negligible, in contrast to the yield, which is a consequence of applications of irrigation regime during the next two periods. For the second period the relationship is linear at R<sup>2</sup>=0.779. According to it, for the preparation of the minimum yield CPP above 6573 m<sup>2</sup>/da to budding period should accumulate, and for example for the preparation of 1000 kg/da – 21725 m<sup>2</sup>/da.

The smaller slope of the line for this period is due to its small duration and lack of time to substantially increase of CPP and the realization of more than 2 irrigations.

2

However formed in this part of vegetation CPP is determinative for the final yield, which was confirmed by the values of R<sup>2</sup>.

Dependence valid for the period of formation and growth of the pods is also linear at R<sup>2</sup> = 0.899.

The longer duration and realized large number of irrigations in this part of the vegetation give a significant impact on the values of

21532 m<sup>2</sup>/da,  
1000 kg/da – 66990 m<sup>2</sup>/da.

R<sup>2</sup>=0.860.

47698 m<sup>2</sup>/da.  
1000 kg/da

108305 m<sup>2</sup>/da,

the CPP in different variants of the experiment, so that the variation with respect to the x-axis covers a wider range.

As a consequence, the slope of the line dependency is larger in comparison with that obtained for the previous period.

According to the same, to obtain a minimum yield, CPP in the third period should be over 21532 m<sup>2</sup>/da, and for yield of 1000 kg/da – 66990 m<sup>2</sup>/da. The relationship between yield and photosynthetic potential, established total for the entire growing season, is also linear at R<sup>2</sup> = 0.860. According to the calculations it is not possible to obtain any yield at values up to 47698 m<sup>2</sup>/da. A yield of 1000 kg/da can be obtained by accumulating values of 108305 m<sup>2</sup>/da, and in the meantime it should provide CPP for the second and third periods.

5. Table 5. Parameters of the relationship "Yield-CPP" for different periods and total

/ periods	/ equation	R <sup>2</sup>
	Y = 0.066x – 433.938	0.779
	Y = 0.022x – 473.695	0.899
–	Y = 0.017x – 787.022	0.860

### CONCLUSIONS

For the formation of a maximum CPP of bean soil 0-60cm moisture in the layer 0-60cm should be over 80% of FC throughout the growing period.



30%,  
80-95%  
(70%  
70 – 90%  
13 18%  
18-36%  
10-12  
20%  
60%  
40 60%.

- Reducing of irrigation norms by 30% cumulative CPP represents 80-95% of the maximum, and assuming a significant water deficit (70% reduction of normal) CPP is 70-90% of maximum CPP. These high values are due to the regular submission of irrigations, although reduced irrigation rates.

- To budding period, in terms of optimal irrigation, between 13 and 18% of the cumulative CPP is formed, thereby reducing irrigation norms these relative values increased, reaching to 18-36% for non-irrigated variants. In terms of the absolute values opposite tendency was observed. During the period of budding and flowering for 10-12 days it is formed about 20% of the aggregate CPP of bean, as practically there is no difference between the variants, but with increase of the amount of irrigated norms absolute values for CPP increase. The most significant part of cumulative CPP is formed during the formation and growing of the pods, while in irrigated conditions it is over 60% and in non- irrigated - between 40 and 60%.

- By increasing the irrigation rates the relative and absolute values of CPP, valid for this period, increased gradually.

There is a close linear relationship between yield and

$$Y = 0.017x - 787.022$$

$$R^2=0.86.$$

$$R^2 \quad 0.779 \quad 0.899.$$

- cumulative photosynthetic potential of garden bean, which meets the equation:  $Y = 0.017x - 787.022$  at  $R^2 = 0.86$ . This type of relationship exists with respect to CPP for the second and third period of the vegetation at values of  $R^2 = 0.779$  and  $0.899$ , respectively. Through this relationship the yield can be predicted before the end of the vegetation.

### / REFERENCES

1. „ . . 1998.
2. „ . . . . . 2007.
3. „ . . 2-3, 555-557. 1973.
4. „ . . 2, 23-35. 1974.
5. „ . . 6, 25-34. 1961.
6. „ . . 1982. “ „, 7-13.
7. „ . . 1963.
8. „ . . . . . 2007.
9. „ . . 2-3, 551-554.
9. **Kalaydjieva R., A. Matev, ZI. Zlatev.** 2015. Influence of irrigation regime on the leaf area and leaf area index of French bean (*Phaseolus vulgaris* L.). Emirates Journal of Food and Agriculture, vol. 27, 2, 171-177.