YELD COMPONENTS OF COMMON BEANS GROWN IN REGULATED WATER DEFICIT CONDITIONS

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Abstract

The aim of this research is to establish the influence of the irrigation regime on the yield components of common beans. The experiment was carried out in the period 2014 – 2016 in the experimental field of Agricultural University of Plovdiv with Dobrudzhanski – 7 variety. The results show that water deficit does not influence the test weight of seeds and the values of the harvest index and has an insignificant influence on the number of inter-nodes and the number of branches on the plant. The cancellation of irrigation in the periods of flowering or seed filling leads to reduction of the number of pods with 5-6% in comparison with their number at optimum irrigation. There is a linear dependence between the number of pods in a plant and the seeds yield at R^2=0.6. The irrigation regime has a significant influence on plant height. The difference between non-irrigated plants and those having optimum irrigation regime is averagely 8 cm. The differences are due to the increasing length of internodes, with the increase of the irrigation rate. The relationship between these two indicators is linear at R^2=0.796.

Key words: *common bean, irrigation, water deficit, yield, yield components*

Introduction

The impact of irrigation regime on beans yield is related to changes in plant growth (leaves, stalk height, number of branches, etc.), as well as to changes in plant structural elements (M.Isk, et al., 2004, A.El-Noemani, et al. 2010). The optimum irrigated plants are more considerable in height and have larger leaf area (B.Loureiro et al., 1990, I.U.Sadek, et al., 2002). Most authors have recorded and proved statistically that beans have increased in number and size, as well as in number of beans in a pod (A.Gomes, et al., 2000, E.Mantovani et al., 2009). Other authors (M.Candilo, et al. 1991, G.Mauromicale, et al., 1999) add that due to 100% of ETM (max. evapotranspiration) compensation, there is increasing of number of branches and the mass of 1000 seeds. All this leads to the yield increase. Researches give data not only for the optimum irrigation impact, but also for the change of the structural elements of beans yield cultivated in regulated water deficit conditions. The unfavourable influence of soil drought leads to reduced size of pods, as well as reduced number of beans in a pod and their weigt (J.Favaro & R.A. Pilatti, 1988, K.Ghassemi-Golezani, et al., 2008, 2010, S.Singh, 2007, R.Oliveira et al., 2008). Similar are the claims of L.Endres, et al. (2010), who emphasize that these negative results emerge in the presence of water stress during the flowering stage even if other stages are supplied with optimum irrigation. It is due to the fact that water supply of plants during this vegetative stage influences significantly the number of kept flowers (S.Hostalacio & I.Valio, 1984). Longer periods between irrigations have influence on the structural elements of yield (dry matter accumulation /DMA/, seeds yield, number of pods on a plant, seed mass, a harvest index) (S.Singh, et al., 2001, A.Bayat, et al. 2010). According to the research results, this irrigation regime does not lead to the reduction of the number of seeds in a bean. Authors have also registered a considerable alteration in the values of the 1000 seeds mass. Except the disturbances in growth and development of plants, T.J. Moser, et al. (1988) point out that yield reduction in the conditions of water stress is strongly related to the number of pods on a plant. The statement of B.Loureiro et al., (1990) is contrary to the previous one. They claim that water supply of bean plants does not influence the number of beans in a pod and their mass. P. Manjeru, et al. (2007) have proven the negative influence of water stress on the structural elements of yield registering a significant reduction of the number of beans in a pod. In order to obtain maximum yields, the water stress has to be avoided during the stages of flowering and growth of pods. According to some authors, the yield size is determined at a great extent by the conditions of leaf growth and the values of leaf area, the leaf-area index and the photosynthesis intensity (A.Nuñez-Barrios, et al., 2005, A.Gomes, et al., 2000).

The aim of present research is to establish the influence of the irrigation regime on the structural elements of beans yield, as well as to find existing dependences between them.

Material and Methods

The experiment was carried out in the period 2014 – 2016 in the experimental field of Agricultural University of Plovdiv. The soil was of alluvial-meadow type, formerly swamped. The used bean variety was *Dobrudzhanski – 7*, the standard variety for the country. The experiment was set up by the block method in four repetitions, with yield plot size of 10 m^2 and planting scheme – 50 x 5 cm (20 plants of 1 linear metre). The experiment included the following variants: 1) without irrigation (control), 2) irrigation with 25% of the maximum irrigation rate (25%m), 3) irrigation with 50% of the maximum irrigation rate (50%m), 4) irrigation with 75% of the maximum irrigation rate (75%m), 5) full irrigation rate (100%m) – optimum irrigation (control), 6) without irrigation in *germination – bud formation* period, 7) without irrigation in *bud formation – flowering* period, 8) without germination in *pod formation – seed filling* period, 9) irrigation with 50% of the maximum irrigation rate (50%m) – through every second furrow moistening.The irrigations at the optimum variant (variant 5) was carried out at decreased soil moisture up to 80% of FC (field capacity) in layer depth 0 - 40 cm. The size of the irrigation rate was estimated for moistening of the whole active soil layer 0 – 60 cm. For this aim, the dynamics of the soil moisture was observed every 5-7 days by the weight method (I. Atanasov, 1972). Watering was carried out at options 2, 3, 4 and 9 at the same time as option 5, but with the relevant corrections of the irrigation rates. At option 9, watering of each inter-row was equal to the watering at the optimum one. Taking into account that every second inter-row was moistened, 50% of the optimum irrigation rate was realized for a unit area. Irrigation was carried out at options 6, 7 and 8 simultaneously with variant 5 – at the same irrigation rate, but only in the relevant stages of vegetation. Watering of experimental areas was by gravity in short closed furrows. The following biometrical indicators were established at all experimental variants: plant height (cm), height of setting the first pod (cm), number of branches on a plant, length of one inter-node (cm), number of inter-nodes on the central stalk, number of inter-nodes on the branches, total number of inter-nodes on a plant, number of pods on a plant, bean yield of one plant (g), straw yield of one plant (g), DMA of one plant (g), number of pods on one inter-node, harvest index, 1000 seeds mass (g), test weight (kg) and seed yield (kg/da). Data for all indicators of the variants and the repetitions by years was processed by the means of a dispersion analysis in order to prove the differences. Dependences between biometric indicators were established through a regressive analysis of the input data.

Results

The influence of the irrigation regime on the values of biometric indicators and beans productivity is determened at a great extent by the year`s meteorological characteristics. Concerning the presipitation for the period May-August, the first experimental year characterized as medium wet (19.8% probability), wtih drought during the third decade of June and the first decade of July. It coincided with the end of the growing period and bud formation – the beginning of flowering stage. The amount of precipitation in the stages of pod foramtion and seed filling were 30 – 40 mm for ten days. It provide at a great extent the evapotranspiration of plants. The second experimental year (2015) was characterized as humid (13.2%probability). Nevertheless, in the period from the third decade of June to the second decade of August the weather dried up; the precipitation for the whole period was barely 44 mm. Practically, it meant that there was drought during the reproduction period of beans. There was goodly amount of precipitation in the third decade of August (136 mm) without having practical significance for yield and its components. There was medium amount of precipitation (41.5%probability) in the period May-August of the third experimental year (2016). Precipitation was distributed equally by decades, although its quality was extremely insufficient. There was barely 70 mm of precipitation during the reproduction period.

The sum of the average daily air temperature for the period May-August of the first experimental year (2014) was 2631°C, characterized as medium with 46.5% probability. The hottest weather was in the third decade of July – the stage of pod formation and seed filling. The second experimental year (2015) was medium warm with temperature sum of 2748°C and 19.1% probability. Significant sum values were registered in the first half of May and the third decade of July. Temperatures lower than the average multiannual ones were registered in the third decade of May (first triple leaf stage) and the third decade of July (mass flowering stage). The warmest year of the three experimental years was 2016 – with 14.1% probability and temperature sum of 2775°C. The temperature during the whole reproduction period was higher than the temperature of the multiannual period. It was clearly observed in the second and third decades of June, which coincided with the stages of bud formation and flowering.

Irrigation Regime

Irrigation regime in open areas agriculture depend directly on the meteorological conditions during the vegetation period. They have influence on the number of irrigations and the size of annual irrigation rate. In the first experimental year there were two times of watering for variants 2, 3, 4, 5 and 9 – in the stages of flowering and pod formation. In the second experimental year there were four times of watering – the first two were realized in the stages of bud formation and flowering, and the other two were in the stages of pod formation and seed filling.

Table 1. Distribution of irrigations by years

<table>
<tr><th>year</th><th>date</th><th colspan="2">T (days)</th><th>phase</th></tr>
<tr><td rowspan="2">2014</td><td>06 VII</td><td colspan="2" rowspan="2">7</td><td>flowering</td></tr>
<tr><td>13 VII</td><td>pod formation</td></tr>
<tr><td rowspan="4">2015</td><td>15 VI</td><td rowspan="2">21</td><td rowspan="4">7</td><td rowspan="2">flowering</td></tr>
<tr><td>06 VII</td></tr>
<tr><td>13 VII</td><td rowspan="2">8</td><td rowspan="2">pod formation & grain filling</td></tr>
<tr><td>21 VII</td></tr>
<tr><td rowspan="3">2016</td><td>21 VI</td><td colspan="2" rowspan="2">15</td><td>beginning of flowering</td></tr>
<tr><td>6 VII</td><td>end of flowering – beginning of grain filling</td></tr>
<tr><td>22 VII</td><td colspan="2">16</td><td>grain filling</td></tr>
<tr><td colspan="5">m – irrigation rate; M – annual irrigation rate; T – period between two irrigations</td></tr>
</table>

Table 2. Number of irrigations and annual irrigation rates by variants – average for 2014 – 2016

Variant	2	3	4	5	6	7	8	9
$\mathbf{M}_{average}$ (mm)	38.9	77.8	116.8	155.7	155.7	105.7	50.0	116.8
Number of irrigations - average	3	3	3	3	3	2	1	3
$\mathbf{m}_{average}$ (mm)	13.0	25.9	38.9	51.2	51.2	52.8	50.0	38.9
M – annual irrigation rate; **m** – irrigation rate								

In the third experimental year there were three times of watering distributed from the stage of flowering to the stage of seed filling. For variants 6, 7 and 8 there were fewer times of watering according to the experiment`s methodology. Table 2 shows the average data for the irrigation regime components by variants.

Influence of the irrigation regime on the structural elements of bean yield

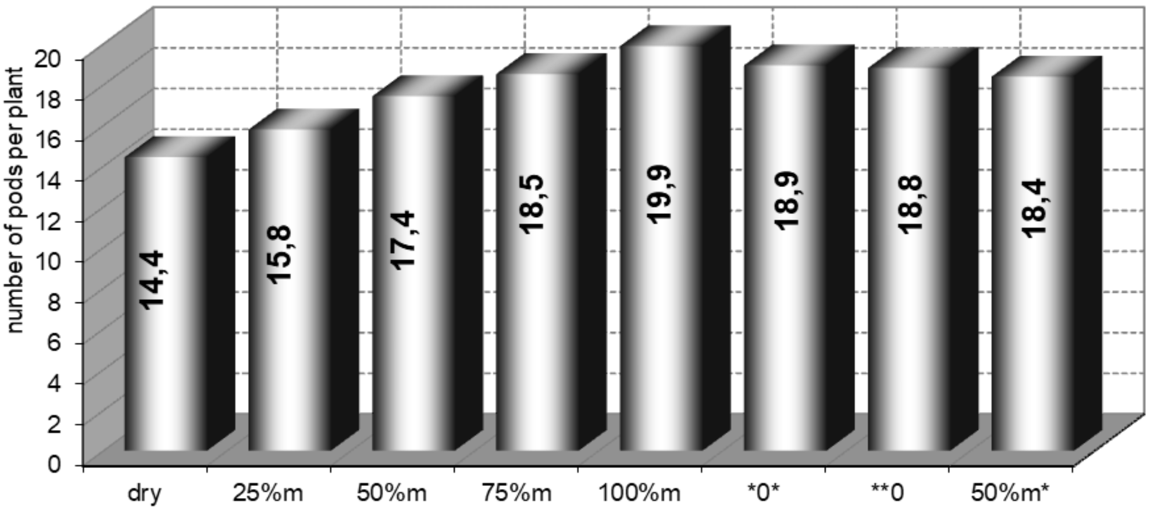
Table 3 shows the average biometrical indicators for the three experimental years by variants.

Table 3. Structural elements of yield by variants on average for the years 2014-2016

indicator	option							
	1	2	3	4	5	7	8	9
Plant height (cm)	32.5	35.0	36.3	37.4	40.1	36.7	37.8	37.5
	GD: P5%=1.9 cm P1%=2.6 cm P0.1%=3.5 cm							
Height of setting the first pod (cm)	15.0	14.9	15.5	14.6	13.9	15.6	15.5	15.6
	GD: P5%=1.0 cm P1%=1.4 cm P0.1%=1.8 cm							
Number of branches	2.5	2.8	3.0	3.1	3.3	3.1	3.1	3.2
	GD: P5%=0.3 P1%=0.4 P0.1%=0.6							
length of one inter-node (cm)	4.6	4.7	4.8	4.9	5.1	4.7	4.9	4.9
	GD: P5%=0.2 cm P1%=0.3 cm P0.1%=0.4 cm							
Number of internodes on the main stalk	7.1	7.5	7.5	7.7	7.9	7.8	7.7	7.6
	GD: P5%=0.3 P1%=0.4 P0.1%=0.5							
Number of internodes on the branches	7.3	8.3	9.9	10.8	12.0	11.2	11.1	10.7
	GD: P5%=1.0 P1%=1.4 P0.1%=1.9							
Number of internodes on a palnt	14.4	15.8	17.4	18.5	19.9	18.9	18.8	18.4
	GD: P5%=1.1 P1%=1.5 P0.1%=2.0							
Number of pods on a plant	7.5	9.5	10.7	11.5	12.0	11.0	11.5	11.2
	GD: P5%=1.4 P1%=1.8 P0.1%=2.5							
Seed yield from a plant (g)	6.4	8.5	9.3	9.8	10.8	9.2	9.6	9.5
	GD: P5%=1.4 g P1%=1.9 g P0.1%=2.6 g							
Straw yield from a palnt (g)	7.3	8.8	9.6	10.0	11.2	10.4	10.3	10.1
DMA from a plant (g)	13.7	17.3	19.0	19.8	21.9	19.6	19.9	19.6
	GD: P5%=1.4 g P1%=3.2 g P0.1%=4.3 g							
Number of pods on an internode	0.52	0.61	0.65	0.66	0.65	0.61	0.65	0.64
	GD: P5%=0.07 P1%=0.10 P0.1%=0.13							
Harvest index	0.468	0.490	0.492	0.496	0.491	0.470	0.483	0.484
	GD: P5%=0.028 P1%=0.038 P0.1%=0.051							
1000 seeds mass (g)	355.2	383.6	405.6	410.5	418.4	399.9	385.9	404.9
	GD: P5%=14.4 g P1%=19.6 g P0.1%=26.5 g							
Test weight (kg)	150.0	149.6	151.0	150.9	151.4	149.7	153.0	151.5
	GD: P5%=3.8 kg P1%=5.2 kg P0.1%=7.1 kg							
Seed yield (kg/da)	142	188	223	242	253	221	187	218
	GD: P5%=14 kg/da P1%=19 kg/da P0.1%=26 kg/da							

According to the results, the difference in water supply of plants does not lead to changes in seeds test weight. At the same time, the increase of irrigation rate leads to an increased grain absolute mass (mass of 1000 seeds), which is statistically warranted. Data for dry matter accumulation /DMA/ and seeds yield shows changes in values according to the water supply, which is statistically warranted. As a result, the harvest index changes insignificantly, statistically unwarranted (between the separate experimental variants). It proves the complex influence of the irrigation regime and the water supply degree on growth, development and productivity of beans. The irrigation regime has weak influence on the number of internodes on the main stalk. It is probably due to stronger characteristics of the variety. The regime has influence to some extent on the number of branches and the number of internodes on them. It is a prerequisite for setting a greater number of pods on a plant. It is statistically warranted for the conditions of the experiment that the number of pods on a plant increases, which is also helped by the increase in the number of pods on an inter-node (fig.1). It is a consequence of the improved conditions of pollination and pod formation, which are realized with the increase of irrigation rates. As a result, it is statistically warranted that the improvement of irrigation regime leads to an increase of seeds yield from one plant. The lack of irrigation during the reproductive period of beans reduces the number of pods on a plant with 5-6%. The irrigation regime has influence on plant's height. The difference between non irrigated plants and these having optimum irrigation regime is almost 8 cm. According to experimental data, these differences are due to the increasing length of internodes with the increase of the irrigation rate. In spite of the fact that the change of these two indicators is unidirectional with the change of yield and the rest of its components, they do not have direct influence on beans productivity. As a minimum indirect impact can be the fact that the prolonged internodes and the plant height give conditions for better light of more developed leaves. As a result, there are better conditions for photosynthesis and better productivity.

Water supply degree has more significant influence on the total number of pods on a plant than the number of pods on the internodes. In both cases branches are more productive than the central stalk - 57% of pods are placed on branches and 43% are on the main stalk. There is a tendency for increasing the number of pods on branches with the improvement of water supply. At the conditions of the current experiment the irrigation regime has influence on the number of internodes on the branches, which is statistically warranted.



%	49.5	47.4	43.3	41.6	39.7	41.0	40.8	41.6	main stalk
	50.5	52.6	56.7	58.4	60.3	59.0	59.2	58.4	branches

Fig.1. Influence of the irrigation regime on the number of pods in a plant and relevant distribution of pods on the central stem and the branches

Plant height depends on the irrigation regime through the inter-node length (fig. 2) and their number on a plant (fig.3). In relation with both indicators, there is a linear dependence at a relatively high coefficient of determination – $R^2 = 0.796$ and $R^2 = 0.703$ correspondingly. Taking into account these results, it can be considered that inter-node length has more significant influence on plant height.

The size of seeds yield depends on the number of pods on a plant. There is an established linear dependence at $R^2 = 0.6$ (fig.4). The conducted regression analysis shows that the seed absolute weight (the 1000 seeds mass) has stronger influence on grain yield. The dependence between them is linear at $R^2 = 0.845$ (fig.5). The dependence between the 1000 seeds mass and the size of relative irrigation rate is a square function, which is presented graphically by a protuberant parabola. It approximate experimental points of all variants and years at a very high coefficient of determination (R^2>0.9). The dependence is presented on fig. 6.

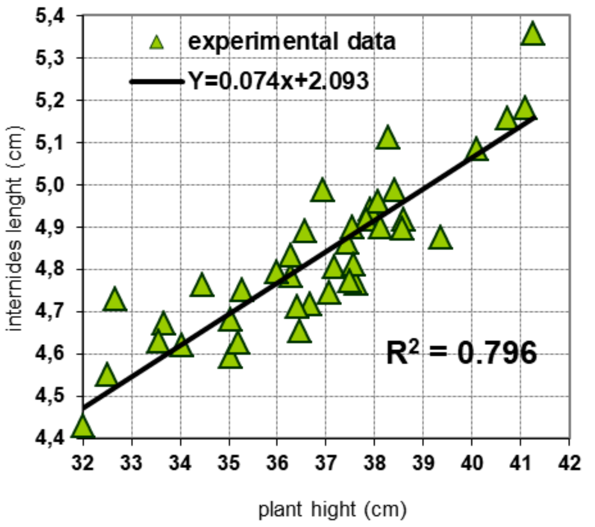


Fig.2. Relation between plant height and inter-node length

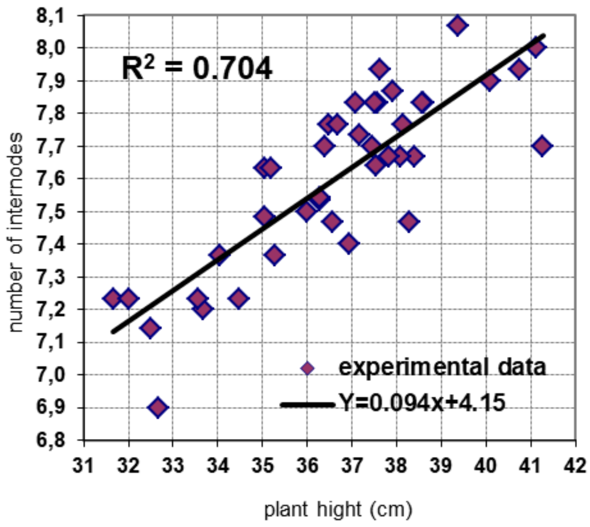


Fig.3. Relation between plant height and the number of inter-nodes on a plant

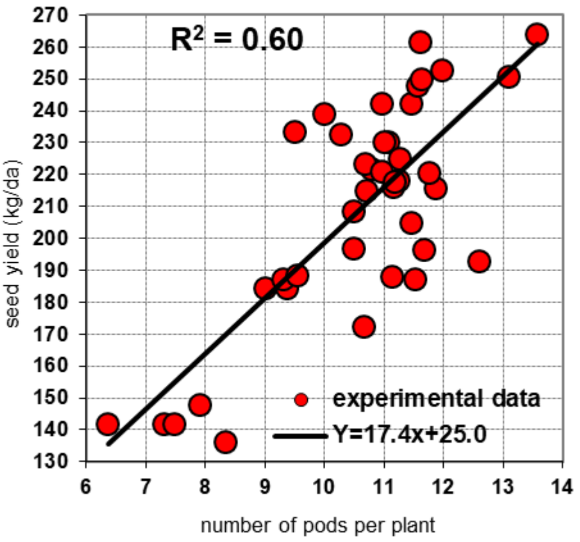


Fig.4. Dependence between number of pods on a plant and seed yield

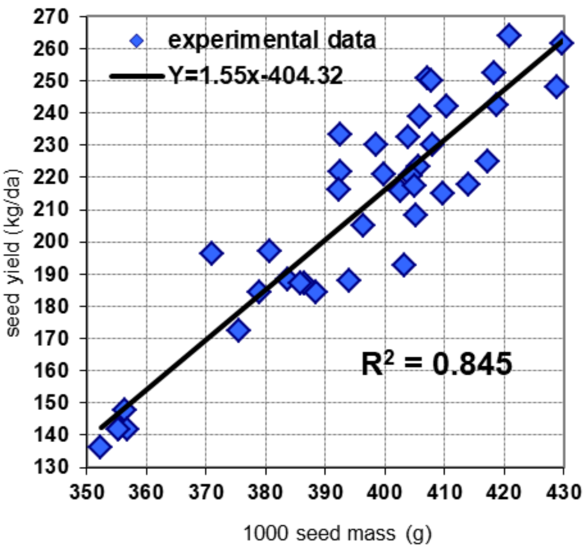


Fig.5. Dependence between the 1000 seed mass and seed yield

The irrigation regime has influence on the rate of accumulating plant biomass, thus it predetermines the size of seeds yield. It is proved by the dependence between DMA and seeds yield (fig.7). The dependence is linear at $R^2 = 0.942$.

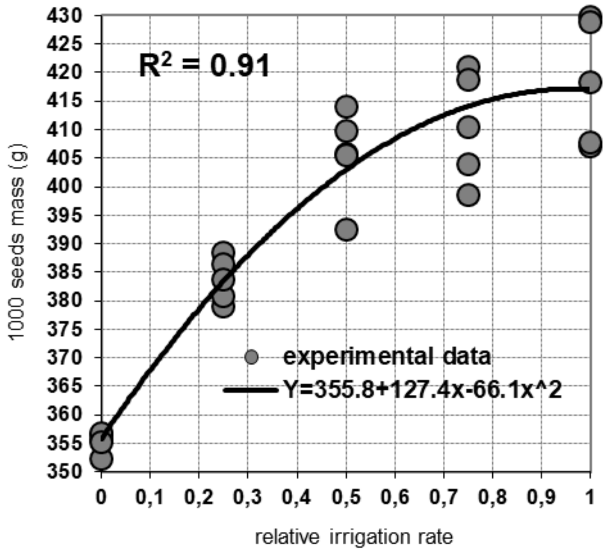


Fig.6. Dependence between the relative irrigation rate and the 1000 seeds mass

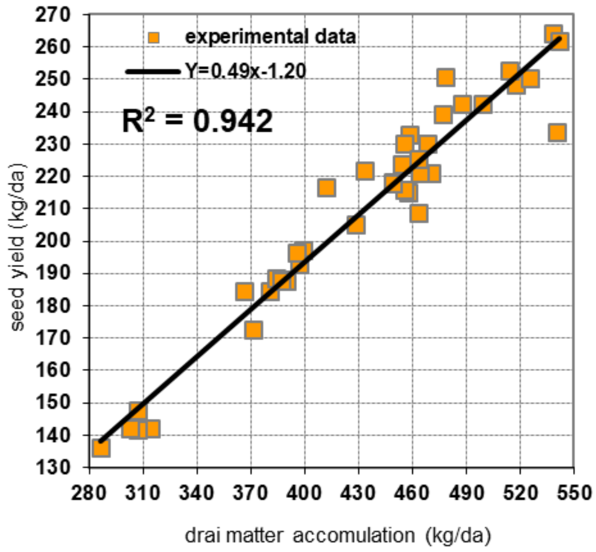


Fig.7. Relation between DMA and seed yield

Conclusions

The irrigation regime does not influence the test weight of seeds and the values of the harvest index. The irrigation regime has an insignificant influence on the number of inter-nodes and the number of branches on the plant.

The increased annual irrigation rate leads to an increased number of pods on a plant, as well as an increased relative share of pods on the branches. The cancellation of irrigation in the periods of *flowering* or *seed filling* leads to reduction of the number of pods with 5-6% in comparison with their number at optimum irrigation. There is a linear dependence between the number of pods in a plant and the seeds yield at R^2=0.6.

The irrigation regime has a significant influence on plant height. The difference between non-irrigated plants and those having optimum irrigation regime is averagely 8 cm. The differences are due to the increasing length of internodes, with the increase of the irrigation rate. The relationship between these two indicators is linear at R^2=0.796.

There is a square relationship between the size of annual irrigation rate and the 1000 seeds mass at $R^2 = 0.91$ and linear relation between the dry matter accumulation and seeds yield at $R^2 = 0.94$.

The parameters characterizing the structural elements of bean yield irrigated every second furrow are similar to those with 50% irrigation of the optimum irrigation norm.

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