# IRRIGATION REGIME FOR BEAN BEANS IN THE CONDITIONS OF THE ROMANIAN PLAIN

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**Abstract**

Unlike other crops, beans have moderate moisture requirements, but are very sensitive to moisture deficiency during flowering and grain formation. It has been established that in the short interval between these phenophases the sensitivity is maximum both in case of excess moisture and moisture deficit. Research has shown that the lack of water during flowering and fruiting greatly reduces production by shortening the duration of these phases of vegetation, by reducing pollen fertility, reducing pods and grain weight. The sensitivity of beans to the deficiency of vapor saturation in the atmosphere during flowering also has negative effects on the harvest. In order to determine to what extent the years of experimentation approach or deviate from the climatic conditions typical of the experimental field, monthly aridity indices were used for the series of years in which the experiments were performed at the studied farms, compared to indices of aridity from a longer period. The highest yields were obtained when the soil moisture at the beginning of flowering was at the field capacity for water and was maintained at the mentioned ceilings until the full formation of the grains. This paper summarizes the results of research on the influence of irrigation on production obtained in 2018-2021, at four farms located in the North Baragan Plain in Braila County.

**Key words**: aridity index, irrigation regime, soil moisture, harvest increase, economic efficiency

Researches regarding the bean irrigation regime were performed in the period 2018-2021, at 4 farms from Campia Baraganului de Nord, Braila county, respectively: SC AGROPET SRL, on vertical chernozem; SC DANAGRI SRL on typical clayey chernozem; SC RINAMIA SRL on cambic chernozem and SC TARRA MADIN SRL on argillaceous chernozem.

The distance between the rows was 40 cm, the sowing norm was 80-100 kg/ha of seed, depending on the variety sown, and the irrigation was done by sprinkling.

In order to determine to what extent the years of experimentation approach or deviate from the climatic conditions typical of the experimental field, monthly aridity indices were used for the series of years in which the experiments were performed at the 4 units studied, compared to indices of aridity from a longer period, for which there are data on the respective company. The frequency on the studied units of the monthly aridity indices, during the bean vegetation period is presented in *figure 1*.

## MATERIAL AND METHOD

In order to determine to what extent the years of experimentation approach or deviate from the climatic conditions typical of the experimental field, monthly aridity indices were used for the series of years in which the experiments were performed at the 4 units studied, compared to indices of aridity from a longer period, for which there are data on the respective company. The frequency on the studied units of the monthly aridity indices, during the bean vegetation period is presented in *figure 1*.

A suggestive indicator for the characterization of aridity is the De Martonne aridity andex ($I_{ar\text{-}DM}$), described by the relation: $I_{ar\text{-}DM} = P/(T_m + 10)$, where P = sum of annual precipitation, and $T_m$ = average annual temperature, at the denominator additionally intervening the value of 10˚C.

The dotted broken line represents the value of the monthly aridity index for the average of the series of years used, the other lines representing ± 10, 30, 50% of the cases. Table 1 analyzes the deviations and ensures the aridity indices compared to 2020 for the experimental years. It is observed that at SC AGROPET SRL the year 2021 is the closest to the atypical year, with the smallest monthly and average deviations during the bean vegetation period and with the highest assurances of the monthly aridity index. The year 2020 showed a slight tendency to increase aridity, and the year 2021 to decrease. And at SC DANAGRI SRL, all the experimental years can be considered as close

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to the average case and with great possibilities of repetition if we take into account the deviation and ensuring the average aridity indices during the bean vegetation period. At SC RINAMIA SRL every year there were large monthly deviations of the aridity indices. At SC TARRA MADIN SRL the year 2018 came very close to the year 2019 having a good insurance of the average monthly aridity index during the vegetation period.

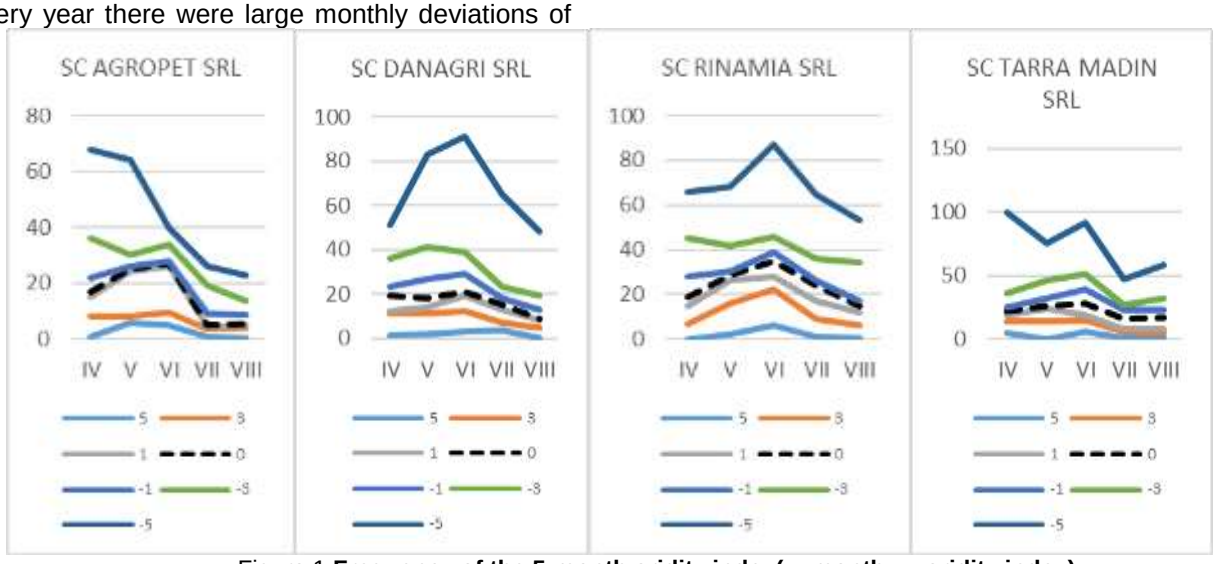


Figura 1 **Frequency of the 5-month aridity index( x-month, y- aridity index)**

Table 1

**Analysis of the aridity index title**

| Unit studied | Year | | Month | | | | | Amount | | | Average over growing seasons |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | IV | V | VI | VII | VII | + | - | total | |
| SC AGROPET SRL | 2019 | deviation | -5.0 | +5.0 | -0.1 | -0.6 | +5.0 | 10.0 | 5.7 | +4.3 | +0.9 |
| | | insurance | 0 | 0 | 49 | 44 | 0 | | | 93 | 18.6 |
| | 2020 | deviation | +5.0 | -0.9 | -2.7 | -3.2 | -2.1 | 5.0 | 8.9 | -3.9 | -0.8 |
| | | insurance | 0 | 41 | 23 | 18 | 29 | | | 110 | 22.0 |
| | 2021 | deviation | +1.6 | +1.3 | +1.1 | -1.4 | +2.5 | 6.5 | 1.4 | +5.1 | +1.0 |
| | | insurance | 34 | 37 | 39 | 36 | 25 | | | 17.1 | 34.2 |
| SC DANAGRI SRL | 2018 | deviation | -2.3 | -3.0 | +1.0 | -3.1 | +1.3 | 2.3 | 8.4 | -6.1 | -1.2 |
| | | insurance | 27 | 20 | 40 | 19 | 37 | | | 143 | 28.6 |
| | 2019 | deviation | -2.1 | +5.0 | +0.5 | -0.7 | -1.2 | 5.5 | 4.0 | +1.5 | +0.3 |
| | | insurance | 29 | 0 | 45 | 43 | 38 | | | 155 | 31.0 |
| | 2020 | deviation | +4.8 | -2.4 | -1.4 | +0.3 | +0.2 | 7.1 | 3.8 | +3.3 | +0.6 |
| | | insurance | 2 | 26 | 36 | 47 | 30 | | | 141 | 28.2 |
| | 2021 | deviation | +2.3 | +0.4 | -1.6 | +0.3 | +2.4 | 5.4 | 1.6 | +3.8 | +0.7 |
| | | insurance | 27 | 46 | 34 | 47 | 26 | | | 180 | 36.0 |
| SC RINAMIA SRL | 2018 | deviation | -0.4 | -0.5 | -0.3 | +3.0 | -0.6 | 0.3 | 9.0 | -8.7 | -1.7 |
| | | insurance | 46 | 0 | 20 | 47 | 44 | | | 157 | 31,4 |
| | 2019 | deviation | -2,3 | +4,5 | -3,6 | +3,5 | +4,0 | 12,0 | 5,9 | +6,1 | +1,2 |
| | | insurance | 27 | 5 | 14 | 15 | 10 | | | 71 | 14.2 |
| | 2020 | deviation | +3.9 | +1.6 | -1.3 | -5.0 | -2.9 | 5.5 | 9.2 | -3.7 | -0.7 |
| | | insurance | 11 | 34 | 37 | 0 | 21 | | | 103 | 20.6 |
| | 2021 | deviation | +0.5 | -3.7 | -0.2 | -1.4 | +3.5 | -4.0 | 5.3 | -1.3 | -0.2 |
| | | insurance | 45 | 13 | 48 | 36 | 15 | | | 157 | 31.4 |
| SC TARRA MADIN SRL | 2018 | deviation | +1.8 | -5.0 | +1.2 | +3.0 | +4.0 | 10.0 | 5.0 | +5.0 | +1.0 |
| | | insurance | 32 | 0 | 38 | 20 | 10 | | | 100 | 20.0 |
| | 2019 | deviation | -2.9 | -3.2 | -3.5 | -2.8 | -5.0 | 0.0 | 17.4 | 17.4 | -3.5 |
| | | insurance | 21 | 18 | 15 | 22 | 0 | | | 76 | 15.2 |
| | 2020 | deviation | +1.1 | +3.8 | +4.3 | -1.2 | -3.4 | 9.2 | 4.6 | +4.6 | +0.9 |
| | | insurance | 39 | 12 | 7 | 38 | 16 | | | 112 | 22.4 |
| | 2021 | deviation | -1.3 | -1.0 | +1.3 | -3.8 | +2.5 | 3.8 | 6.1 | -2.3 | -0.4 |
| | | insurance | 37 | 40 | 37 | 12 | 25 | | | 151 | 30.2 |

## RESULTS AND DISCUSSIONS

***SC AGROPET SRL***. The beans followed the crop after the sunflower. The fertilizers were applied in spring, when working the soil with the cultivator, before sowing, as follows: the non-irrigated variant ($V_0$) received 20 kg/ha N, and the irrigated variants ($V_1$ to $V_3$) 40 kg/ha N. *Table 2* shows the amount of atmospheric precipitation during the vegetation period, the irrigation rate and

the number of waterings as well as the production result for the 3 years of experimentation.

The minimum soil moisture ceilings made by the irrigated variants were: $V_1$ -60-65% CC; $V_2$ - 65-70% CC; $V_3$ – 70-75% CC. The blank ($V_0$) has been non-irrigated.

From the analysis of the soil moisture dynamics it is found that in all the years of experimentation with the non-irrigated variant ($V_0$) due to the winter moisture reserves, the soil was well supplied with water at sowing (over 70% CC). Watering was applied from the appearance of flower buds to ripening.

Table 2

**Scheme of irrigation regime and bean production at SC AGROPET SRL**

| Year | Rainfall (mm) | Irrigation standard ($m^3$/ha/nr watering) | | | Grain yield (kg/ha) | | | | Harvest increase (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | from $V_0$ | | | from $V_1$ | |
| | | $V_1$ | $V_2$ | $V_3$ | $V_0$(Mt) | $V_1$ | $V_2$ | $V_3$ | $V_1$ | $V_2$ | $V_3$ | $V_2$ | $V_3$ |
| 2018 | 220.2 | 900/2 | 1600/3 | 2300/4 | 992±22 | 1520±27 | 2353±126 | 2511±63 | 53 | 137 | 153 | 48 | 65 |
| 2019 | 238.7 | 600/1 | 1200/2 | 1600/3 | 1075±18 | 1363±26 | 1702±44 | 1968±28 | 26 | 58 | 83 | 24 | 44 |
| 2020 | 173.2 | 900/1 | 1600/3 | 2000/4 | 850±24 | 1485±42 | 1864±58 | 2120±63 | 74 | 118 | 149 | 25 | 42 |

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From the analysis of the soil moisture dynamics it is found that in all the years of experimentation with the non-irrigated variant ($V_0$) due to the winter moisture reserves, the soil was well supplied with water at sowing (over 70% CC). Watering was applied from the appearance of flower buds to ripening. The precipitations from April-May maintained the soil humidity over 60% CC until the appearance of the first flowers. From this date the soil moisture began to decrease towards the wilting coefficient. During flowering the soil moisture was maintained at a minimum ceiling of 50-53% CC. Watering applied to irrigation variants from the beginning of flowering until the full formation of the grains brought very large increases in production (528-1519 kg/ha).

The water recovery coefficient ($V_0$ – 2.11; $V_1$ – 1.47, $V_3$ – 1.78 $m^3$ water/kg of grains), shows that in this year's conditions (with aridity indices close to 2019 in April-July) the variant that received 2 waterings during flowering and one watering at the beginning of the grain formation ($V_2$) made the best use of water. In $V_3$ the last watering was applied late, after the full formation of the grains, and in $V_1$ the watering was sufficient.

The variant with a single watering during flowering brought a production increase of 74% (+ 635 kg/ha). The water recovery coefficient was: $V_0$ -2.74; $V_1$ – 1.59; $V_2$ – 1.26; $V_3$ – 1.18.

In all the years of experimentation with the irrigated variants, the vegetation period was extended by up to 20 days, by prolonging the flowering. The leaf area and in general the production of twigs was higher for the irrigated variants (up to double compared to $V_0$ to $V_3$). In the case of the non-irrigated variant, it was observed that the drying of the leaves started during flowering. The number of fertile pods was higher in the irrigated variants with 1-3 pods per plant. Also, the weight of 1000 grains was higher reaching $V_3$ on average up to 13% more than $V_0$. In none of the experimental years did the need to irrigate the beans appear before sowing or before the appearance of floral buttons.

The results obtained at SC AGROPET SRL can confirm the importance of applying watering from the beginning of flowering until the full formation of the bean. The lower water recovery coefficient for irrigated variants shows that in this area the beans make very good use of irrigation water.

The highest yields (4021-4780 kg/ha) were obtained at $V_3$, in which the soil moisture was maintained at a minimum ceiling of 70-75% CC until the formation of grains by applying 3-4 waterings, with a norm of irrigation of 1600-2300 $m^3$/ha. At $V_2$ the minimum ceiling of soil moisture of 65-70% CC, achieved by 2-3 waterings with irrigation rate of 1200-1600 $m^3$/ha production was 2700-3353 kg/ha, with an increase of 58-137% non-irrigated face.

The correlations between the obtained productions and the total water consumption by evaporation and transpiration are expressed by a linear equation of form $y = 501.5 + 0.64x$, and the result indicates possibilities to increase the production of beans by irrigation, of course accompanied by agrotechnical measures corresponding to.

***SC DANAGRI SRL***. Beans followed in crop rotation after corn. Fertilizers were applied in the following total doses: for the non-irrigated variant ($V_0$) 20 kg/ha N + 30 kg/ha $P_2O_5$; for irrigated variants ($V_1$ to $V_3$) 30 kg/ha N +60 kg/ha $P_2O_5$ + 20 kg/ha $K_2O$, being distributed in two stages, half at the preparation of the land before sowing and half before flowering. *Table 3* presents the synthesis results for the 4 years of experimentation.

Table 3

**Irrigation regime and bean production at SC DANAGRI SRL**

| Year | Total precipitation over the growing season (mm) | Irrigation standard ($m^3$/ha/nr watering) | | | Grain yield (kg/ha) | | | | Production aid (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | from $V_0$ | | | Compared to $V_1$ | |
| | | $V_1$ | $V_2$ | $V_3$ | $V_0$ (Mt) | $V_1$ | $V_2$ | $V_3$ | $V_1$ | $V_2$ | $V_3$ | $V_2$ | $V_3$ |
| 2018 | 286.9 | 800/1 | 950/1 | 2250/3 | 751±25 | 1712±125 | 1942±76 | 2304±111 | 128 | 158 | 206 | 13 | 34 |
| 2019 | 225.4 | 800/1 | 1200/2 | 1700/3 | 1288±39 | 1785±68 | 2113±5 | 2312±109 | 39 | 56 | 80 | 18 | 29 |
| 2020 | 196.7 | 500/1 | - | 1600/3 | 1612±26 | 1865±48 | - | 2682±51 | 16 | - | 66 | - | 43 |
| 2021 | 212.9 | 900/2 | 1400/3 | - | 1010±28 | 1304±23 | 1526±23 | - | 29 | 61 | - | 17 | - |

***SC RINAMIA SRL***. Beans followed in the first two years after maize and the following years after sunflower. The fertilizers applied as follows: On non-irrigated version 20 kg/ha N + 30 kg/ha $P_2O_5$ in spring to work with the grower; on irrigated varieties ($V_1$ to $V_3$) 15 kg/ha N+ 40 kg/ha $P_2O_5$+ 20 kg/ha $K_2O$ in spring to work with the grower and 15 kg/ha N+ 20kg/ha $P_2O_5$+ 20 kg/ha $K_2O$ at the beginning of flowering.

The production results obtained during the 4 years of experimentation are presented in *table 4*.

The minimum ceilings of soil moisture made for irrigated variants were $V_1$- 65-70% CC; $V_2$- 70-75% CC; $V_3$- 75-80% CC.

Table 4

**Scheme of the irrigation regime and bean production at SC RINAMIA SRL**

| Year | Total precipitation over the growing season (mm) | Irrigation standard ($m^3$/ha/nr watering) | | | Grain yield (kg/ha) | | | | Production aid (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | from $V_0$ | | | from $V_1$ | |
| | | $V_1$ | $V_2$ | $V_3$ | $V_0$(Mt) | $V_1$ | $V_2$ | $V_3$ | $V_1$ | $V_2$ | $V_3$ | $V_2$ | $V_3$ |
| 2018 | 359.3 | 800/4 | 1400/2 | 1900/3 | 1478±73 | 1778±32 | 1805±33 | 2056±19 | 20 | 22 | 39 | 1 | 16 |
| 2019 | 278.2 | 1150/2 | 2450/4 | - | 895±23 | 1380±46 | 1724±78 | - | 51 | 93 | - | 24 | - |
| 2020 | 276.9 | 800/1 | - | 1100/2 | 1653±13 | 2025±44 | - | 2135±60 | 22 | 27 | 29 | 3 | 5 |
| 2021 | 416.8 | 800/1 | 565/1 | 900/2 | 946±52 | 1497±71 | 1581±88 | 1839±49 | 58 | 67 | 94 | 5 | 22 |

Watering applied (at $V_1$) late, during baking, practically did not bring an increase of production. The water recovery coefficient ($V_0$-2.65; $V_1$-2.93; $V_3$-1.98) shows that only $V_3$ in which the waterings were applied to flowering and to the full formation of the pods made good use of the water. In this variant, the highest production increase was obtained (114%), respectively 1215 kg/ha of grains and the highest production of all the years of experimentation (2284 kg/ha) confirming that in the years with accentuated drought in July it is necessary to watering is applied to the formation of pods in this area as well.

In 2018, the year with good insurance of the aridity index (31.4), during the vegetation period it showed the tendency of decreasing the aridity. The flowering was much prolonged in all variants, and at $V_0$ a high production was obtained (4478 kg/ha). The water recovery coefficient ($V_0$- 2.62; $V_1$- 2.69; $V_2$- 3.13; $V_3$- 2.98) shows that only $V_1$ to which watering was applied at the end of flowering when the soil moisture decreased to 60% CC, made good use of water. $V_2$ and $V_3$ had a higher water recovery coefficient than non-irrigated, because some waterings were followed by heavy rains. In 2019 the productions were lower than the other years, the culture suffering from hail. The plants from the irrigated variants with more fragile foliage suffered more and recovered after about 10 days. The soil moisture in the non-irrigated version was maintained at over 60% CC until the end of flowering and never decreased to the wilting coefficient.

($V_0$) were applied to the land preparation with the cultivator before sowing: 10 kg/ha N + 20 kg/ha $P_2O_5$, and before flowering 10 kg/ha N + 10 kg/ha $P_2O_5$. For irrigated variants ($V_1$ and $V_2$) in the first stage 15 kg/ha N + 40 kg/ha $P_2O_5$ + 20 kg/ha $K_2O$ were applied, and before flowering 15 kg/ha N + 20 kg/ha $P_2O_5$ + 20 kg/ha $K_2O$.

The minimum ceilings of soil moisture made for irrigated variants were: $V_1$- 75-80% CC; $V_2$ – 80-85% CC.

From the analysis of the production results from the years of experimentation (*table 5*) it is found that the lowest production for non-irrigated culture was obtained in 2018, due to the faulty distribution of precipitation during flowering.

Table 5

**Irrigation scheme and bean production at SC TARRA MADIN SRL**

| Year | Total precipitation over the growing season (mm) | Irrigation standard ($m^3$/ha/nr watering) | | Grain yield (kg/ha) | | | Production aid (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | From $V_0$ | | from to $V_1$ |
| | | $V_1$ | $V_2$ | $V_0$ (Mt) | $V_1$ | $V_2$ | $V_1$ | $V_2$ | $V_2$ |
| 2018 | 259.2 | 1500/2 | 1600/3 | 681±238 | 1232±27 | 1252±27 | 81 | 84 | 2 |
| 2019 | 540.4 | 900/2 | 1400/3 | 1449±40 | 1932±63 | 2181±30 | 29 | 46 | 58 |
| 2020 | 262.7 | 1600/2 | 2250/3 | 1562±104 | 2916±35 | 3116±8 | 87 | 99 | 13 |
| 2021 | 272.6 | 1050/1 | 2600/3 | 2151±109 | 2524±83 | 2541±51 | 18 | 18 | - |

In 2018, flowering and fruiting lasted a little due to heat and strong insolation. In the irrigated variants, a production almost double compared to the non-irrigated variant was obtained. The increase in production at $V_2$, of only 2% compared to $V_1$, shows that the two waterings applied in addition to flowering and after the formation of the grains, when the soil moisture was over 75% CC, were not necessary. The water recovery coefficient was: $V_0$ - 3.43; $V_1$ - 2.76; $V_2$ - 2.88.

In 2019, the soil moisture for the non-irrigated version was maintained throughout the vegetation period at over 70% CC. Although the year was rainy, production increases of 29-46% were obtained through irrigation. Also this year, the water recovery coefficient was lower for the irrigated variants ($V_0$ - 3.57; $V_1$ - 2.85; $V_2$ - 3.01).

In 2020, until the beginning of flowering, the soil moisture remained at over 65% CC, and at flowering-fruiting it decreased to 70% CC. This year, with the high tendency of aridity in April, May, the highest production increases were obtained for the irrigated variants compared to the non-irrigated one (87-99%). Watering was applied to the appearance of the first flower buds and the formation of the first pods at $V_1$, and at $V_2$ received an additional watering during flowering. The water recovery coefficient was: $V_0$- 1.45; $V_1$ - 1.33; $V_2$ - 1.47.

In 2021, for the non-irrigated variant, a very good production was obtained (3151 kg/ha), as a result of the good distribution of precipitations during the vegetation period. Also due to this fact, in $V_2$ with three waterings an increase of 18% was obtained, equal to the one obtained in case of applying a single watering ($V_1$). The production obtained for this variant shows that in the years with a good distribution of precipitation during the bean vegetation period and with high humidity, especially during flowering-fruiting, a single watering at the beginning of flowering was sufficient. The water recovery coefficient was: $V_0$- 1.54; $V_1$- 1.61; $V_2$- 2.18. $V_3$ did not make good use of the water because the irrigation rate was too high for this rainy year.

The results obtained at SC TARRA MADIN SRL show that by irrigating the beans, very high yields could be obtained, up to 4116 kg/ha. These productions were made at a minimum soil moisture ceiling of 75-85% CC, and the irrigation norm was 1050-2600 $m^3$/ha, distributed in 1-3 waterings (in normal years 2-3 waterings, and in rainy years a watering at flowering).

The correlation between the total water consumed and the obtained productions is represented by a linear equation of form y = 590 + 0.316 x.

## CONCLUSION

The results obtained from the experiences with the irrigation regime for beans in the Northern Baragan Campia show that large increases in production can be achieved by irrigation. According to the press release, at SC AGROPET SRL, production of up to 4511 kg/ha was obtained with a 153% increase as compared to the non-irrigated version. On typical-uterus cernozioma, at SC DANAGRI SRL produced outputs up to 3682 kg/ha with a 66% increase compared to non-irrigated (in other years the increase was up to 206%). The minimum ceiling of soil humidity for the variants that brought the highest economic output increase was: SC AGROPET SRL-80 - 85% CC; SC DANAGRI SRL – 70-75% CC; SC RINAMIA SRL – 80-85% CC; SC TARRA MADIN SR-75-80% CC. Until the occurrence of the flower buttons, the soil moisture may be maintained at a minimum of 2-5% lower ceiling.

The highest yields were achieved when the soil moisture at the beginning of flowering was at the water field capacity and remained at the said ceilings until the grain was fully formed.

In order to achieve the said minimum ceilings, an irrigation standard of 1600-2030 $m^3$/ha was required divided into 3-4 wetting at SC AGROPET SRL, 600-2250 $m^3$/ha in 2-3 wetting at SC DANAGRI SRL, 1100-2000 $m^3$/ha in 2-3 wetting at SC RINAMIA SRL and 1150-2600 $m^3$/ha in 2-3 waterings.

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