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DIFFERENT SOYBEAN PLANT POPULATIONS UNDER CENTRAL PIVOT IRRIGATION

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ABSTRACT: Planting density can influence the competitiveness among plants mainly by water, nutrients and solar radiation, directly affecting yield. The purpose of this study was to evaluate the productivity of different soybean cultivars at different planting populations under irrigated and rainfed conditions. The experiment was conducted during the 2014/15 growing season, under center pivot irrigation in Chapadão do Sul – MS, Brazil. The experimental design was randomized complete block design with split-plot, as follows: Irrigated and Rainfed (plots) x Six cultivars (subplots) x Three Plant Populations (sub-subplots) with 4 replications. The irrigation management was realized by Penman-Monteith-FAO method. The cultivars used were: NA 5909 RR, DM 5958 IPRO, Anta 82 RR, M 7110 IPRO, Desafio RR and M 7739 IPRO. Populations indicated by the holders of the seeds were tested, and also population 20% above and 20% below with the hypothesis that in different humidity conditions, different cultivars may have different answers depending on their populations. In rainfed condition productivity and mass of one hundred grains were influenced by water deficit. Cultivar Desafio RR presented the best performance under irrigation, with productivity of 6174 kg ha^{-1}.

KEYWORDS: Plant density; Irrigated Soybean; Deficit irrigation; Soybean Yield.

INTRODUCTION

The rainfall irregularity is becoming more frequent with the climate changes in recent years, even in regions with high incidence and with rainfall seasons considered to be well defined (GAVA, et al., 2016).

In soybean crop, lack of precipitation, even during small periods, can cause water deficit and compromise productivity. This occurrence at decisive moments can cause considerable reductions in productivity. According to GAVA (2014) water deficit, even at low intensity, can cause losses in soy production, depending on the phenological stage in which the crop is found. The author states that when it occurs in the grain fillings, the productivity drop can reach 64% in relation to irrigated areas.

According to VIVIAN et al. (2013) soybean yield is linked to climatic randomness, with water deficit being the main limiting productive agent. When studying the relative yield of the soybean crop as a function of the irrigation depth, simulating 9 crops with different planting dates and different crop cycles, these authors concluded that for the Passo Fundo microregion in the State of Rio Grande do Sul, in the period (1993 to 2006), in all simulated scenarios there was a need for water supply, and it was observed significant reduction in yield as a result of water deficit, where yield reductions as function of percentage of irrigation depth varied between 25 and 45 % of maximum relative.

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FLUMIGNAN et al. 2015 studying the need for soy irrigation through the simulation with historical data, , also concluded that for the Southern region of the State of Mato Grosso do Sul there is a need for additional irrigation.

Researches show that there is need for soybean crop irrigation in different regions in Brazil.

Brazil has high potential to increase its irrigated areas, generating higher soybean yields which still a little explored in the irrigation field. It is necessary researches to determine the genotypes that present greater adaptability in this system, as well as the ideal cultivation population, aiming better exploit the genetic production potential of each cultivar.

HEIFFIG (2009) states that there are already adapted soybean cultivars for the different Brazilian regions with productivity potential of 6000 kg ha^{-1}. However, due to aspects related to crop management and climatic character, i.e. lack of rainfall, productivity averages are still far below that.

The great variety of cultivars in the market make necessary to know each one by differentiating its characteristics through research. According to KUSS (2006) soybean productivity is affected by intrinsic factors of its different cultivars, with a difference in the response between them to irrigation management and plant population. Thus, irrigation and the choice of genetic material are factors that affect crop yield. According to him, another important fact regarding the plant population is that the photosynthetic rate may vary depending on the arrangement of the plant population, the air and the soil humidity, directly affecting the crop yield. Therefore, the hypothesis is established on possible interaction between soybean plant population and water availability.

The population of soybean plants can be altered so that the crop yield become high due to the increase on absorption area by solar radiation which will be defined according to the requirements of the used cultivar, besides the amount of available water during the crop cycle. Thus, there is need for studies that determine the genetic material with the greatest productive potential under irrigated conditions as well as the need to change the plant population when irrigation is adopted. Thus, the objective of this study was to evaluate the yield of soybean cultivars in different plant populations under irrigated and no irrigated conditions.

MATERIAL AND METHODS

The study was carried out from October 2014 to February 2015, under central pivot, in the experimental area of the Agricultural Research Support Foundation of Chapadão, Chapadão do Sul - MS, (latitude 18 ° 46’49” S, longitude 52 ° 38’51” W and altitude of 810 meters).

The climate of the region is defined as tropical with dry season (Aw), according to the Köppen classification with average annual temperature of 25°C and average annual rainfall of 1800 mm.

The soil of the area is classified as Dystrophic Red Latosol; moderate A horizon, having a clay texture (SANTOS et al., 2013).

The experimental design was randomized block with sub-subdivided plots in irrigation factor (irrigated and not irrigated) as subplots, and six cultivars (NA 5909 RR, DM 5958 IPRO, Anta 82 RR, M 7110 IPRO, Desafio RR and M 7739 IPRO), and in the sub-subplots three populations of plants (populations indicated by the respective seed holders for the region, and populations 20% above and 20% below the recommendation), with 4 replications, totaling 144 experimental units (Table 1).

TABLE 1. Soybean plant populations used for each cultivar, Chapadão do Sul-MS, 2015.

Record	Lenght	Maturation Group	Population 1	Population 2*	Population 3
Name	Days		In Thousand plants ha^{-1}		
NA 5909 RR	100	5.9	444.4	555.6	666.7
DM 5958 IPRO	100	5.8	444.4	555.6	666.7
Anta 82 RR	120	7.4	444.4	555.6	666.7
M 7110 IPRO	115	6.8	288.9	400.0	511.1
Desafio RR	120	7.4	288.9	400.0	511.1
M 7739 IPRO	125	7.7	222.2	333.3	444.4

In order to enable the division of the plots allowing irrigation control, the sowing was in strips from the center of the central pivot to its limit, allowing the harvest and respecting the different cycles of the varieties without trampling the other plots (Figure 1).

FIGURE 1. Aerial image of the experiment location, under Central Pivot in the Agricultural Research Support Foundation of Chapadão, Chapadão do Sul-MS, 2015.

Seeding was carried out on October 15, 2014, in the no-tillage system in corn crop residues of second crop by Jumil seeder/fertilizer; model 2670-PD of 5 rows spaced 0.45 m. Each experimental unit consisted of 5 lines with 10 meters of length, spacing between lines 0.45 m considering two lines of the ends as border.

The fertilization followed the soil chemical analysis (Table 2) where 150 kg ha^{-1} of NPK formulation 11-52-00 was applied in the sowing line for all plots and afterwards the application of 200 kg ha^{-1} of potassium chloride in cover at the phenological stage V2. In the treatment of seeds, the product Standak Top was applied at the dose of 100 mL ha^{-1}, on the recommendation of the company that owns the product.

TABLE 2. Soil chemical attributes.

Depth	P resin	OM	pH $CaCl_2$	K^+	Ca^{2+}	Mg^{2+}	H+Al	Al^{3+}	BS	CEC
cm	mg dm^{-3}	g dm^{-3}		-------------------- $cmol_c$ dm^{-3} -------------------						
0-20	26.3	31.0	5.5	0.31	3.80	1.50	3.2	0.02	63.7	8.8
20-40	14.3	27.2	5.1	0.18	1.60	0.80	3.5	0.05	42.4	6.1

OM – Organic matter; BS – Basis Saturation, CEC – Cation exchange capacity

The applications of fungicides, pest and weed control and other fertilization were carried out according to the crop need, following recommendation from the Chapadao Foundation.

Irrigation management was carried out using meteorological data. The crop evapotranspiration (ETc) was obtained by the product of Reference Evapotranspiration (ETo) and the Crop Coefficient (Kc). The estimates of ETo were obtained by the Penman-Monteith-FAO method (Equation 1), according to ALLEN et al. (1998), using data from an automatic meteorological station (Code A730) of the National Institute of Meteorology (INMET), located in the municipality of Chapadão do Sul, near to the experimental area.

$$ET_0 = \frac{0.408\ \Delta\ (Rn - G) + \gamma \frac{900}{(T+273)} U_2 (es - ea)}{\Delta + \gamma\ (1 + 0.34\ U_2)} \quad (1)$$

In which:

ETo - reference evapotranspiration (mm d^{-1});

Rn - net radiation at the crop surface (MJ m^{-2} d^{-1});
G - soil heat flux density (MJ m^{-2} d^{-1}) (null value for use of the daily scale model);

T - air temperature at 2 m height (ºC);

U_2 - wind speed at 2 m height (m s^{-1});

es - saturation vapour pressure (kPa);

ea - actual vapour pressure (kPa);

Δ - slope vapour pressure curve (kPa $ºC^{-1}$), and

γ - psychrometric constant (kPa $ºC^{-1}$).

Soil physical-water parameters were obtained in the Soil Laboratory of Chapadão do Sul Campus (UFMS / CPCS) and are presented in Table 3.

TABLE 3. Hydro-physical analysis of the soil in the experimental area, Chapadão do Sul-MS, 2015.

Layer	**FC**	**PWP**	**WCA**	**Ds**	**Dp**	**TP**	**Granulometric Fractions**			**Textural Class**
(cm)	(cm^3 cm^{-3})		(mm cm^{-1})	(g cm^{-3})		(%)	Sand	Silte	Clay	
							(%)			
0 - 15	0.413	0.282	1.76	1.34	2.65	53.6	39.24	6.68	54.08	Clayey
15 - 30	0.383	0.262	1.74	1.44	2.65	48.4	36.76	4.56	58.68	

FC - Moisture in the field capacity to the matric potential (ψm) of 0.3 atm; PWP - Permanent wilting point in ψm at15 atm; CAD - Water capacity available; Ds – Density of the soil; Dp - Density of particles; TP - Total soil porosity

Irrigations were performed only when soil moisture approached the lower limit of the soil Real Water Capacity (RWC), calculated by [eq. (2)].

$$RWC = 10 * (FC - PWP) * ds * Z * f \quad (2)$$

In what:

RWC - Real Water Capacity (mm);

θ_{FC} - Field Capacity (cm^3 cm^{-3});

*θ*PMP - Permanent wilting point (cm^3 cm^{-3});

ds – Density of the Soil (g cm^{-3});

Z - Effective Depth of the Radicular System (cm), and

F - Factor of availability of the culture (adm).

Therefore, it was not adopted a fixed irrigation shift, but rather, the moment when the plant had consumed all readily available water, using the standard *F* for soybean in the local condition of 0.45, correcting it daily for Water Fraction Available from the Soil (WFA), according to the methodology adapted from ALLEN et al., 1998 (Equation 3).

$$WFA = Ftab + 0.04 * (ETo - ETc) \quad (3)$$

In what:

WFA - water fraction available from the soil (adm);

Ftab - availability factor of the crop tabulated for soybean in the local condition (*Ftab*= 0.45) (adm);

ETo - reference evapotranspiration (mm d^{-1}),

ETc - crop evapotranspiration (mm d^{-1}).

The highest frequency occurred during the grain filling stage. This management aimed to reduce the wetting of the plants (which favors the appearance of pests and diseases), increase soil aeration, induce deepening of the root system, reduce nutrient leaching, and harness rainwater, since the soil kept near the lower limit of the RWC when a rainfall occurs, it has porous space to be stored in the soil as opposed to when the soil is always kept close to the field capacity.

The date of harvest was variable for each cultivar, according to their respective cycles (Table 1). The two central lines were evaluated with 4 meters of extension in each experimental unit (3.6 m^2), and then the grain moisture was measured through the Ghaka 650 humidity measuring equipment, allowing later moisture correction at 13%. It was also carried out the counting of 100 random grains of each harvested plot and weighed with a subsequent correction of the water content to 13%.

Statistical analysis of the data was performed through the ASSISTAT Version 7.7 beta program. An analysis of variance (anova) was performed to compare the means and interaction between treatments. In the unfolding of the double and triple iterations was performed the Tukey's test.

RESULTS AND DISCUSSION

Rainfall records during the growing cycle, as well as the variation in soil water storage for no irrigation condition, are presented in Figure 2. In order to guarantee standard plant irrigations were also carried out in rainfed area, however only up to the vegetative stage V2.

At 105 days after emergence (DAE) there was a reduction in soil water storage, in addition to readily available water (for Availability Coefficient of 0.45), which reached an accumulated ETc of -10 mm after a period of 7 days without rain. There were three other moments when soil moisture approached the lower limit of RWC, on 11/19/2014 (beginning of flowering), 12/22/2015 and 01/15/2015 (Figure 2).

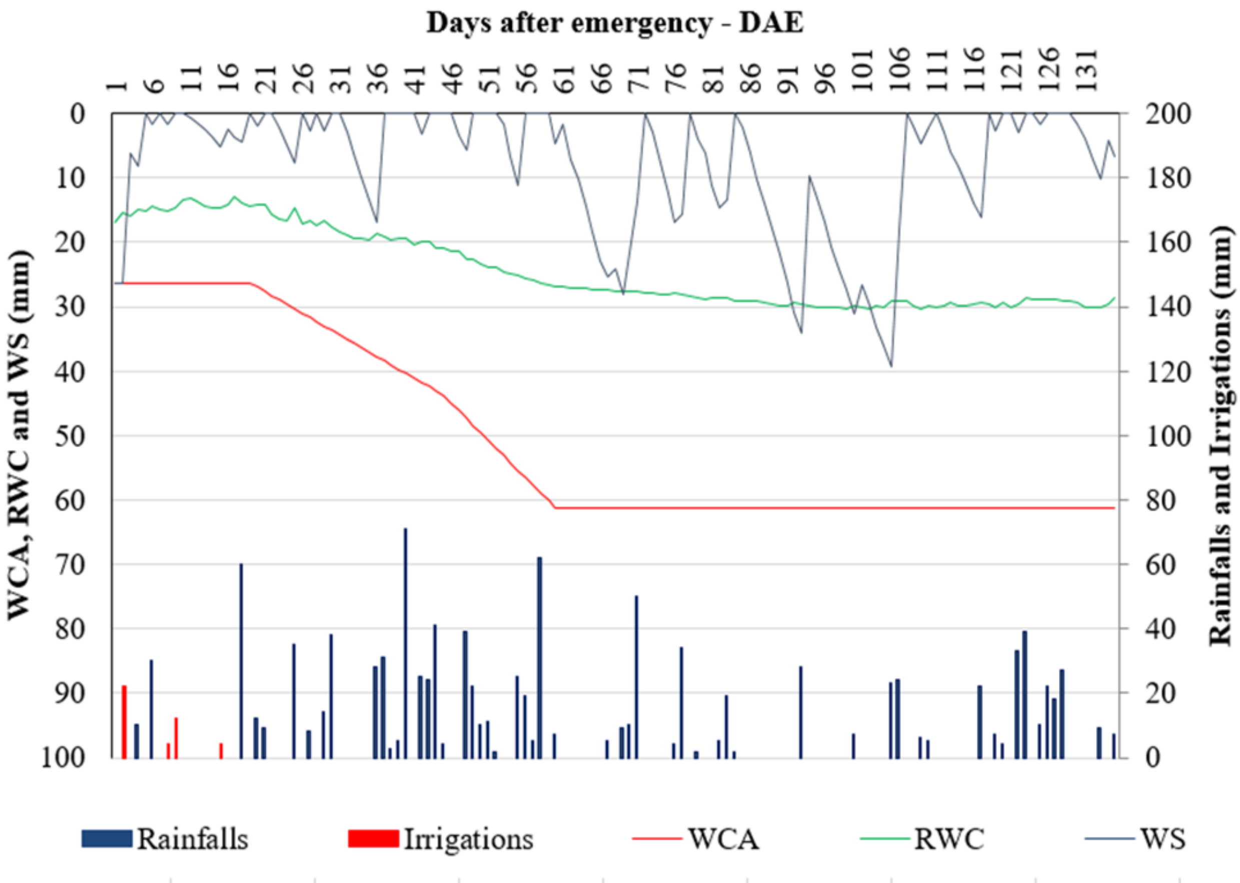

FIGURE 2. Rainfalls in the experiment area, water capacity available (WCA), real water capacity (RWC) and water storage (WS) in the soil during the soybean 2014/15 growing season, Chapadão do Sul-MS, 2015.

Moderate deficits occurred during the vegetative phase of soybean, beginning of flowering and grain fillings, varying with the cycle of each cultivar, occurring at 36, 69, 93, 100 and 105 days after emergence of the seedlings (periods of 6, 13, 10, 6 and 4 days without rain, respectively). The third and fourth periods without rain caused water deficits in the grain filling stage for cultivars of larger cycles. However, the super precocious cultivars (NA 5909 RR and DM 5958 IPRO) were already in physiological maturation, and therefore did not suffer from this deficit (Figure 2).

In irrigated treatments, as the irrigation operation was carried out whenever the soil moisture approached the lower limit of its real water capacity, no water deficit occurred (Figure 3).

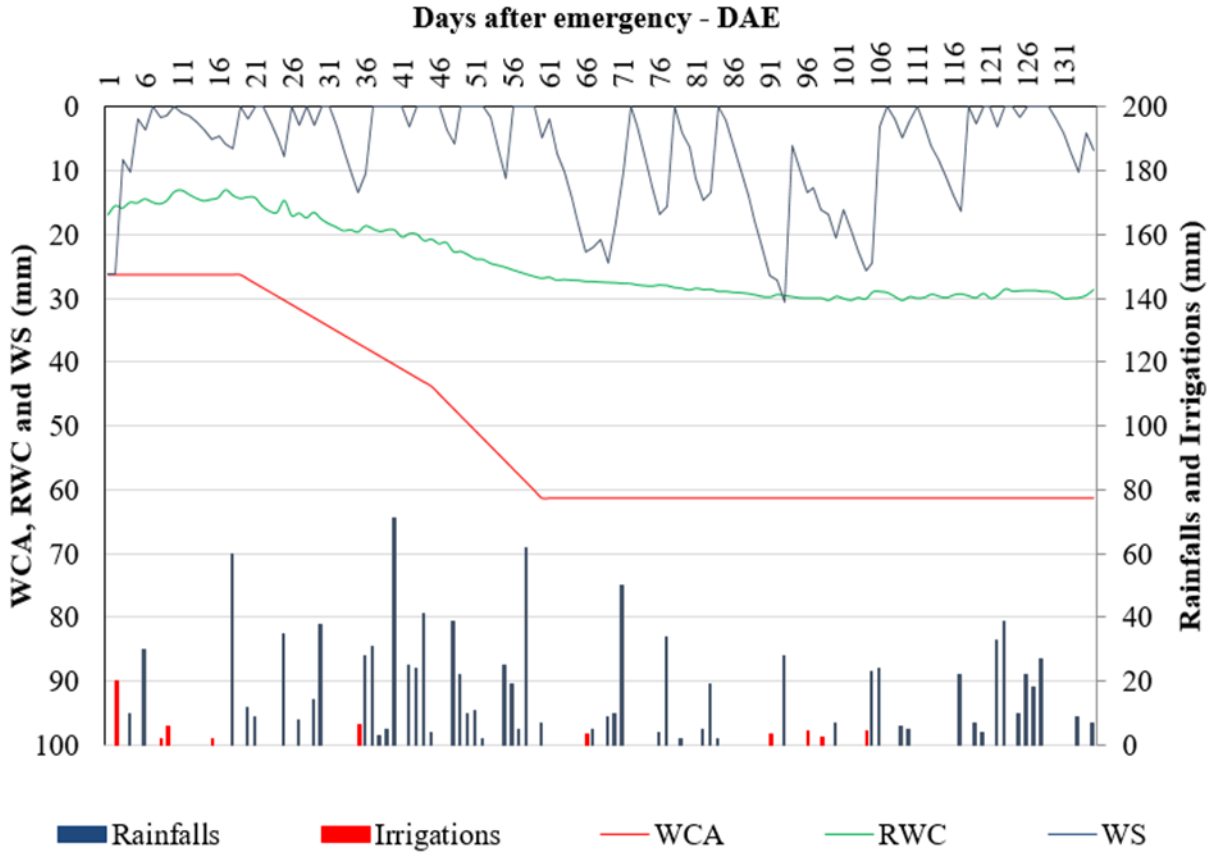

FIGURE 3. Water storage (WS) Rainfall at the experiment area, real water capacity (RWC) highlighting the irrigations that prevented the occurrence of deficit, Chapadão do Sul-MS, 2015.

The occurrence of water deficit only in the grain filling stage is so severe that the reduction of productivity is equivalent to the reduction with deficits occurring throughout the crop cycle (GAVA, et al., 2015). This is because the plant that suffers deficits from the initial stage adapts to the condition of soil moisture restriction during its cycle, whereas, plants grown in soil that has available water until the stage of grain filling, and at this stage suffers deficit, will result in larger reductions in grain mass and consequently in productivity (Figure 3), corroborating FLUMIGNAN et al. 2015. Thus, researches show that there is need for irrigation of soybean crop in different regions of Brazil.

There was a difference in productivity between irrigation and no irrigation (rainfed) and between cultivars and plant populations. In addition to interaction between all factors (Table 4).

TABLE 4. Analysis of variance of irrigated soybean yield data and rainfed in different plant populations, Chapadão do Sul - MS, 2015.

SV	MSD	F
Blocks	41497.4	0.265 ns
Irrigation (Ta)	38709769.6	177.328 **
Residue – a	1566848.9	
Plots		
Cultivars (Tb)	660527.2	4.216 **
Interaction (TaxTb)	1292269.0	5.920 **
Residue – b	218295.2	
Subplots		
Plant populations (Tc)	3785667.3	29.122 **
Interaction (TaxTc)	1142181.2	8.786 **
Interaction (TbxTc)	1242523.5	9.558 **
Interaction (TaxTbxTc)	725662.3	5.582 **
Residue – c	129994.8	
Total		

SV - Source of variation; MSD - Mean Square of Deviations; F - factor F.
** - significant at the 1% probability level (p <0.01); [ns] - Not significant.

The data of the interaction between irrigation, cultivars and plant populations are presented in Table 5, where the differentiation of the means by the Test F is presented by lowercase letters between the means of the columns and by capital letters between the averages of the lines. In the table the separation between no irrigated (rainfed) and irrigated was made with the intention of facilitating the comparison on reader's part. However, its differentiation is by the capital letters in all column.

Plant populations showed little influence on productivity. The smallest population tested resulted in a decrease in productivity only for M 7110 IPRO in no irrigation (rainfed) condition and for the Desafio RR and M 7739 IPRO cultivars in irrigation condition. Thus, soybean productivity is influenced by the plant population, depending on the used cultivar and water condition.

TABLE 5. Unfolding of the interaction Irrigation x Cultivars x Plant Population to irrigated soybean yield and rainfed in different plant populations, Chapadão do Sul – MS, 2015.

Irrigation - Cultivars		Plant Population		
		Population 1	Population 2	Population 3
Rainfed	Na 5909 RR	4806 A ab	4698 A bc	4488 A bcd
	DM 5958 IPRO	3918 A cdef	4224 A cd	4242 A cd
	Anta 82 RR	4122 A bcde	3804 A d	3672 A d
	M 7110 IPRO	3618 B def	4290 A cd	4524 A bcd
	Desafio RR	3276 A ef	3798 A d	3774 A d
	M 7739 IPRO	3504 A ef	3816 A d	3792 A d
Irrigated	Na 5909 RR	5004 A a	5004 A bc	4938 A bc
	DM 5958 IPRO	4896 A ab	4896 A bc	5268 A ab
	Anta 82 RR	5112 A a	5298 A b	5316 A ab
	M 7110 IPRO	4710 A abc	4938 A bc	4950 A bc
	Desafio RR	3210 B f	6174 A a	6066 A a
	M 7739 IPRO	4404 B abcd	5502 A ab	5292 A ab

*Means followed by lower case letters in the column and upper case in the row differ from each other by the Tukey test at the 5% probability level. Minimum significant difference (Dms) for columns = 14.886. Dms for lines = 10.5744.

The increase in population above-recommended did not represent an increase in production in any of the tested conditions. In addition, the increase in population may represent an unnecessary cost to the producer. The cost of seeds and their treatment in the Central-West region represents 13% of the total cost of agricultural inputs and operations adopted in soybean cultivation, according to VILELA et al. (2015). In this sense, increases in the population of plants are unnecessary even in irrigated conditions by central pivot.

Irrigation contributed significantly to the productivity increase, allowing the attainment of 6174 kg ha^{-1} with the cultivar Desafio RR, in the recommended population. Representing an increase of 60% in relation to the no irrigated (rainfed) condition, corroborating with VIVAN, et al. (2013) and GAVA et al. (2015) that found increases in productivity of the same order of magnitude for soybean crop.

Similar values of productivity in central pivot area were also found by SILVA et al. (2012), who studying the physical-hydric properties, root development and soybean productivity in two types of soil management, reached productivities of 6000 kg ha^{-1}.

The highest no irrigated (rainfed) yield was achieved with cultivar NA 5909 RR, with yield of 4806 kg ha^{-1}. This same cultivar did not present an increase in productivity when irrigated, because there was no water deficit during its development cycle (super precocious, 100 days). Therefore, combination situations of planting date and genetic material can occur which there is no response to irrigation. In this case, the low level of humidity, close to the limit of the RWC for the occurrence of water deficit that occurred at 100 and 105 DAE did not influence. However, the cultivar DM 5958 IPRO of the same cycle showed significantly lower productivity in no irrigation (rainfed) and similar to the NA 5909 RR at irrigated, showing more sensitive to the effects of low soil moisture and responsive to irrigation.

In general, the cultivars that most produced with irrigation were the ones that the least produced on no irrigated (rainfed). Reinforcing the hypothesis that the productivity increase obtained with irrigation is directly related to the interaction to the genotype with irrigated environment, corroborating with the assertion that these differences are related to the genetic characteristics of each specific cultivar and the way in which the plants respond to the environment (EMBRAPA, 2011).

Another option of soybean population that has been tested is the practice of cross-sowing. SILVA et al. (2015) reached about 4980 kg ha^{-1} in rainfed conditions when using the cross-sowing system, maintaining the recommended fertilization and with twice the recommended population (about 800 thousand plants per hectare). However, these authors concluded that although the production was the largest in this situation, the costs were very high, stating that conventional sowing of parallel lines still shows the highest net revenue, being more profitable to the producer.

For the variable mass of 100 grains there was a difference between irrigation and rainfed, and also between cultivars. There was interaction between irrigation factors and cultivars, but there was no interaction of any of the factors with the population (Table 6).

TABLE 6. Analysis of variance of data of hundred soybean grains mass irrigated and rainfed in different plant populations, Chapadão do Sul – MS, 2015.

SV	MSD	F	
Blocks	1.171	0.673	ns
Irrigation (Ta)	197.168	113.335	**
Residue – a	1.740		
Plots			
Cultivars (Tb)	27.087	27.827	**
Interaction (TaxTb)	7.196	7.393	**
Residue – b	0.973		
Subplots			
Plant populations (Tc)	0.173	0.192	ns
Interaction (Ta*Tc)	1.284	1.419	ns
Interaction (Tb*Tc)	1.637	1.809	ns
Interaction (TaxTbxTc)	1.122	1.240	ns
Residue – c	0.905		
Total			

QM - Mean Square of Deviations; F - factor F.
** - significant at the 1% probability level (p <0.01); ns - not significant

The irrigation provided higher average mass of 100 grains. The cultivar M 7110 IPRO presented a greater mass of hundred grains among the tested cultivars, both in the not irrigated (rainfed) and irrigated, thus showing that this is a genetic characteristic of this cultivar. However, this was different from the others in the rainfed area, and did not differ from the irrigated M 7739 IPRO. The cultivar Anta 82 RR resulted in lower mass of 100 grains (Table 7).

Changes in plant population had no effect on grain mass (Table 7).

TABLE 7. Average data in grams obtained for mass of hundred soybean grains irrigated and rainfed in different plant populations, Chapadão do Sul - MS, 2015.

Irrigation	Mean				
Rainfed	16.1		b		
Irrigated	18.5	a			
CV (%) = 6.97	dms = 0.49				
Cultivars					
NA 5909 RR	17.5		b		
DM 5958 IPRO	17.5		b		
Anta 82 RR	16.1				d
M 7110 IPRO	19.2	a			
Desafio RR	16.5			c	d
M 7739 IPRO	17.0		b	c	
CV (%) = 6.73	dms = 0.87				
Plant Population					
Population 1	17.2	a			
Population 2	17.4	a			
Population 3	17.3	a			
CV (%) = 5.38	dms = 0.46				

CV - Coefficient of variation; Dms - Minimum significant difference.

As shown in Table 8, the mean mass of 100 grains of all cultivars planted in the irrigated area exceeded the means of those sown under no irrigated (rainfed), corroborating with LUDWIG et al. (2011) favorable conditions of water availability, tend to increase the grain mass.

TABLE 8. Unfolding of irrigation x cultivars interaction for mass of hundred soybean grains irrigated and rainfed, Chapadão do Sul – MS, 2015.

	NA 5909 RR	DM 5958 IPRO	Anta 82 RR	M 7110 IPRO	Desafio RR	M 7739 IPRO
	grams (g)					
Rainfed	16.8 bB	16.7 bB	15.0 bC	18.4 bA	15.0 bC	15.0 bC
Irrigated	18.2 aBC	18.3 aBC	17.2 aC	19.9 aA	18.1 aBC	19.1 aAB

* Averages followed by lower case letters in the column and upper case in the row differ from each other by Tukey test at the 5% probability level. Dms for columns = 0.8513. Dms for rows = 1.2247

Grain mass is affected more strongly when water deficit occurs in the grain filling stage (GAVA et al., 2015), explaining the higher averages obtained in irrigated cultivation in relation to the rainfed. However, the mass of 100 grains was not affected by the plant population (Table 7).

CONCLUSIONS

The soybean productivity is influenced by the plant population, depending exclusively on the used cultivar and water condition. However, some genotypes do not respond to irrigation or population changes.

The cultivar Desafio RR presented productivity of 6174 kg ha^{-1} under irrigated condition against 3798 kg ha^{-1} in the rainfed.

Soybean irrigation allows productivity increases on more than 60%.

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REFERENCES

ALLEN, R.G.; PEREIRA, L.S.; RAES, D.; SMITH, M. **Crop evapotranspiration.** Rome: FAO, 1998. 301 p. (Irrigation Paper, 56).

EMBRAPA – EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. Tecnologias de Produção de Soja - Região Central do Brasil 2012 e 2013. In: **Sistemas de Produção.** Londrina: Embrapa Soja, 2011. 261p.

FLUMIGNAN, D.L.; ALMEIDA, A.C.S; GARCIA, R.A. **Necessidade de irrigação complementar da soja na região sul de Mato Grosso do Sul.** Dourados: Embrapa Agropecuária Oeste, 2015. 8p. (Circular técnica, 34).

GAVA, R. **Os efeitos do estresse hídrico na cultura da soja (Glycine Max, (L.) Merrill.).** 2014. 123 f. Tese (Doutorado em Irrigação e Drenagem) - Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba, 2014.

GAVA, R.; FRIZZONE, J.A.; SNYDER, R.L.; JOSE, J.V.; FRAGA JUNIOR, E.F.; PERBONI, A. Estresse hídrico em diferentes fases da cultura da soja. **Revista Brasileira de Agricultura Irrigada**, Fortaleza, v.9, n.6, p. 349 - 359, 2015.

GAVA, R.; FRIZZONE, J.A.; SNYDER, R.L.; DE ALMEIDA, B.M.; DE FREITAS, P.S.L.; REZENDE, R. Estratégias de manejo de déficit hídrico na irrigação da cultura da soja. **Brazilian Journal of Biosystems Engineering**, Tupã, v.10, n.3, p. 305-315, 2016

HEIFFIG, L.S.**Plasticidade da cultura da soja (Glycinemax (L.) Merril) em diferentes arranjos espaciais.** 2009. 219 f. Dissertação (Mestrado em Fitotecnia) - Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba, 2009.

KUSS, R.C.R. **Populações de plantas e estratégias de irrigação na cultura da soja.** 2006. 81 f. Dissertação (Mestrado em Engenharia Agrícola) – Universidade Federal de Santa Maria, Santa Maria, 2006.

LUDWIG, M.P.; DUTRA, L.M.C.; LUCCA FILHO, O.A.; ZABOT, L.; JAUER, A.; UHRY, D. Populações de plantas na cultura da soja em cultivares convencionais e Roundup ReadyTM. **Revista Ceres.** Viçosa, MG, v.58, n.3, p.305-313, jun. 2011.

SANTOS, H. G.; JACOMINE, P. K. T.; ANJOS, L. H. C.; OLIVEIRA, V. A.; LUMBRERAS, J. F.; COELHO, M. R.; ALMEIDA, J. A.; CUNHA, T. J. F.; OLIVEIRA, J. B. (Ed.). **Sistema brasileiro de classificação de solos**. 3. ed. Rio de Janeiro: Embrapa Solos, 2013. 353 p.

SILVA, M.A.A. e.; AZEVEDO, L.P. de.; SAAD, J.C.C.; MICHELS, R.N. Propriedades Físico-hídricas, desenvolvimento radicular e produtividade da soja em dois tipos de manejos de solo. **Irriga,** Botucatu, v.17, n.3, p.387 - 396, 2012.

SILVA, P.R.A.; TAVARES, L.A.F.; SOUSA, S.F.G. de; CORREIA, T.P.S.; RIQUETTI, N.B. Rentabilidade na semeadura cruzada da cultura da soja. **Revista Brasileira de Engenharia Agrícola Ambiental**, Campina Grande, v.19, n.3, p.293–297, 2015.

VILELA, R.G.; ARF, M.V.; TOMQUELSKI, G.V.; DIAS, A.R.; ANSELMO, J.L. **Estimativa do custo de produção do cultivo de soja na região dos chapadões** - Ano Agrícola 2014/15. Soja e Milho 2014/2015. Chapadão do Sul: Fundação Chapadão, 2015. p.218-222.

VIVAN, G.A.; PEITER, M.X.; ROBAINA, A.D.; BARBOZA, F.S.; BUSKE, T.C. Rendimento relativo da cultura da soja em função da lâmina de irrigação. **Irriga**, Botucatu, v.18, n.2, p.282-292, 2013.