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EFFECTS OF WEAR OF PRESSURE REGULATING VALVES FROM A CENTER PIVOT IRRIGATION IN ITS UNIFORMITY OF WATER APPLICATION AND OPTIMUM DEPTH OF BEAN IRRIGATION

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ABSTRACT: Considering the influence on performance of PRV's water application uniformity of center pivot irrigation systems, this study had the aim to compare, under simulated conditions of two distinct wear PRV's (new PRV and PRV with more than 8000h of use) the values of water application uniformity, optimum water application depth and optimum productivity of bean *(Phaseolus vulgaris)*. Results showed that worn PRV causes a 5.1% reduction on center pivot water application uniformity coefficient value. After correcting the water-yield function of the bean crop for the values of water application uniformity provided by new and used PRV, it was observed changes on the values of total seasonal irrigation depth that maximizes bean yield (350 mm for new PRV and 346 mm for used PRV), and changes also on the maximum bean yield (2815 kg / ha for new PRV and 2611 kg / ha for used PRV). Considering only the variable energy costs for pumping the irrigation water, the wear of the PRV causes a R$ 485 / ha reduction on contribution margin.

KEYWORD: center pivot, irrigation, uniformity.

EFEITO DO DESGASTE DAS VÁLVULAS REGULADORAS DE PRESSÃO DE UM PIVÔCENTRAL NA SUA UNIFORMIDADE DE APLICAÇÃO DE ÁGUA E NA LÂMINA ÓTIMADE IRRIGAÇÃO DO FEIJOEIRO

RESUMO: Considerando a influência exercida pelas VRP na uniformidade de aplicação de água de um pivô central, este trabalho teve como objetivo comparar valores simulados para duas condições distintas de desgaste das VRP's (VRP novas e VRP com mais de 8000h de uso) de uniformidade de aplicação de água, lâmina ótima de aplicação de água e produtividade ótima

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do feijão (*Phaseolus vulgaris*). Os resultados indicam que para as duas condições estudadas houve uma redução de 5,1% no coeficiente de uniformidade de aplicação. Após a correção da função de produção do feijoeiro pelos coeficientes de uniformidade com VRP novas e com mais de 8000h de uso, foram observadas diferenças nos valores da lâmina que maximiza a produção da cultura (350 mm para VRP novas e 345mm para VRP usadas), e nas produtividades máximas correspondentes (2815 kg/ha para VRP nova e 2611 kg/ha para a VRP usada). Considerando somente o custo do bombeamento de água, o desgaste das VRP causa uma redução na margem de contribuição de R$485/ha

PALAVRAS CHAVE: pivô central, irrigação, uniformidade.

INTRODUCTION

Given the scarcity of water resources in Brazil and in the world, irrigating producer faces increasing charges in the efficient and rational use of water and to minimize the environmental impacts of irrigation. To ensure that better efficiency is essential to have a good uniformity in the application of water from irrigation systems, as this factor has direct impact on both the water consumption and energy consumption.

The pressure regulating valve (PRV) installed in each of the emitters of the center pivot machines are fundamental to the application of a uniform water depth throughout the extent of the area irrigated by pivot as they allow correct any variations of pressure along the lateral line, preventing these pressure variations to be transmitted directly to the emitters compromising the flow thereof and hence the uniformity of water.

The influence of the PRV in the uniform water application can be easily observed in a study Klar et al. (2001), which compared the performance of two center pivot equipment before and after the exchange of their regulating valves. In this study it was reported that the value of uniformity coefficient Cristiansen (UC_c) went from 58% to 89% in one of the equipment, and 67% to 88% in the other.

According to Leira et al. (2011), it is assumed that the decrease of the irrigation uniformity caused by the worn set PRV- emitter would force the irrigator over time, irrigating in greater amounts to compensate the water deficit. This will certainly influence the operating costs of irrigation.

In this context, the study of changes in the value of the application uniformity coefficient and great water depths in bean crops, due to the wear of the PRV-emitter sets, is of fundamental importance to ensure the most efficient use of water and energy for the irrigation system, ensuring best productive and economic results to the irrigator.

MATERIAL AND METHODS

The experiments were carried out at the Hydraulics Laboratory of the University of Lavras where were evaluated joint compounds i-Wob Senninger emitter coupled to a pressure regulating valve (PRV) with nominal pressure of 69 kPa, the VALLEY model 10 PSI PSR10-½ - 15GPM with drawn from the central pivot after 8000 hours of use. PRV-emitter pairs of sets were used for each of thirty-two nozzles of different diameters distributed in the machine.

The created bench for testing allowed installation in parallel of two copies of the emitter-PRV set of same nozzle diameter, operating with the same inlet pressure. To determine the pressure load set at the entrance, it was used a pressure transducer, DMP-01 DP model (Lamon Products Ltd.) with precision of 0.2 m. To determine the flow of each pair of assemblies operating simultaneously a magnetic flow meter, Model Conaut-Krohne- IFS400w / 6, was used.

An Excel spread sheet, prepared following the method described by Brown (2001), was used to determine the values of K and x parameters of potential model given in Equation 1, which best fit to the pairs of measured values pressure load on the input and PRV flow of the transponder assembly for each nozzle diameter.

$$Q = KH^{x} \qquad (1)$$

Where:

Q - flow of the transponder assembly VRP-10psi- iWob (m^3h^{-1});

K - constant of proportionality ($m^3h^{-1}m^{-x}$);

H - pressure load applied at the input of the regulating valve (m);

x - exponent of the head pressure at the inlet of the VRP-10psi- iWob.

With the values of the adjusted parameters it was possible to determine the characteristic equation of PRV-emitter assemblies for each of the different nozzle diameters.

The field trial was conducted on the property of Agricultural Itograss Alto Mogiana Ltda, located in the Municipality of Bom Sucesso. – MG. It was conducted an altimetric surveying of four different positions assumed by the lateral line in the irrigated area, generating four distinct topographic profiles.

For the acquisition of the real data of head pressure distribution, pressure transducers were installed on pivot point and also at 1st, 2nd, 3rd, 5th, 7th and 8th towers. All these transducers were programmed to record pressure values in the time interval set at five minutes while the center pivot operation time.

Using Bernoulli's principle of energy conservation, it was possible to estimate the energy available from the central pivot point on each of the four measured data. It was used head pressure on the pivot point, the coordinates of the survey and the flow base measured at the pump outlet.

To estimate the total head loss pressure observed along the line used to calculate the energy difference (Equation 2) in each section of the eight measured points on the side line and the power from the pivot point.

$$hf_{total} = E_0 - \left(H_n + h_{emitter} + \frac{V^2}{2g} + Z_n\right) \qquad (2)$$

Where

hf_{total}- Total head loss pressure in the lateral line (m);

E_0 - Energy available at pivot point (m);

H_n - Measured head pressure on the tower last n (m);

$h_{emitter}$ - Emitter height (m)

v - Water velocity in the tube (ms^{-1});

g - Acceleration of gravity (ms^{-2}).

z_n - The last tower height (m);

To determine the distribution of the total pressure drop along the lateral line, it was used as correction factor in Equation 3, proposed by Chu and Moe (1972) where x is the distance desired position in relation to the total length of the wing (r / L).

$$hf(r) = hf_{total}\frac{15}{8}\left(x - \frac{2x^3}{3} + \frac{x^5}{5}\right) \qquad (3)$$

Onde:

hf(r) – Head loss pressure in drop point r of the lateral line;

x - Ratio between the total point r length of the side line (r / L)

To estimate the distribution of head pressure on the wing on each output of the emitters, and thus calculate a corresponding flow, was used to Equation 4 below.

$$H_i = E_0 - Z_i - hf(r) \qquad (4)$$

Where:

H_i – Head pressure of emitter i (m);

Z_i – i Emitter height (m).

Uniformity coefficients compared in this study comprised two distinct uptime times of center pivot equipment. The first, in 2011, shortly after its installation in the area and the second in 2016, after 8000h of use.

In 2011 and 2016 the uniformity of distribution of water was estimated according to the recommendations of the ABNT NBR 14244 (1998) for each evaluation period. For the evaluation after 8000h of use was also used an alternative method, based on the distribution of head pressure where it was possible to calculate the flow rates for each PRV-emitter assembly using the adjusted potential equations, as well as the corresponding areas calculated by Equation 5 for each set. With the turnover time of the equipment set at 21h a day, it was possible to estimate the depths applied and normal distribution (Figure 01).

$$A = \pi\left[\left(r_s + \frac{S_{s+1}}{2}\right)^2 - \left(r_s - \frac{S_s}{2}\right)^2\right] \qquad (5)$$

Onde:

A - Area irrigated by the emitter (m²);

r_s- Emitter turning radius (m);

S_{s+1}- Distance to the rear emitter (m);

S_s= Distance to the preceding emitter (m).

The calculation of the coefficient of water application uniformity (Equation 6) for the two situations was made following equation Christiansen (1942), adapted by Heerman &Hein (1968).

$$UC_c = 100\left[1 - \frac{\frac{\sum_{s=1}^{n}|L_i - \bar{L}| * A_i}{\sum A_i}}{\bar{L}}\right] \qquad (6)$$

Where:

UC_c: Christiansen Uniformity Coefficient (%);

L_i: Depht applied in each subfield irrigated i th (mm);

$\bar{L}$: Average depth of water applied in the irrigated area (mm);

A_i: i th irrigated Subarea (m²).

According to Von Bernuth (1982), the relation between the depth of irrigation applied and crop production is called production function, and can be represented by a polynomial function, which in certain situations present a satisfactory adjustment. The production function used in this study corresponds to a second degree polynomial, which has been obtained by Saad (1996), cited by Castiblanco (2009) and is represented by Equation 7.

$$\overline{\mathrm{Y}}(\overline{\mathrm{L}}) = -14275 + 97{,}676\overline{\mathrm{L}} - 0{,}139\overline{\mathrm{L}}^2 \qquad (7)$$

Onde :

$\bar{Y}$: Average productivity of irrigated ($kg\ ha^{-1}$);

$\bar{L}$: Average depth of water applied (mm).

Von Bernuth (1982) mentions that, Hart (1961) showed that when the blade has applied normal distribution, UC_C is equal to the uniformity coefficient of Hart (UC_H). Thus, for the correction of production function (Equation 7) have uniformity coefficient by Equation 8.

$$\overline{\mathrm{Y}}(\overline{\mathrm{L}}) = -14275 + 97{,}676\bar{L} - 0{,}139\bar{L}^2\left\{1 + 1{,}570\left(1 - \frac{UC_H}{100}\right)^2\right\} \qquad (8)$$

deriving corrected output function by UC_H described by Equation 8 and equating to zero, we get the water depth which maximizes production, and can be represented by Equation 9.

$$\mathrm{Lmax} = \frac{-97{,}676}{-0{,}278\left[1+1{,}570\left(1-\frac{\mathrm{UC_H}}{100}\right)^2\right]} \qquad (9)$$

To demonstrate the influence of the wear of the PRV-emitter sets on the water application uniformity coefficient and consequently the optimal depth production in monetary values, it analyzed the difference in contribution margin for the two proposed situations.

Simply saying, the contribution margin can be understood as the gross profit, which is considered the difference the sale price with the cost of production of a certain product (SEBRAE, 2004). Fixed costs are not considered, capital costs, depreciation and *pro labore*, thus differentiating profit or profitability of production.

So for the contribution margin (Equation 10) analyzed in this study were considered, the sales value of the bean kilogram and the cost of water equal to the cost of pumping.

$$MC = \overline{\mathrm{Y}}(\overline{\mathrm{L}}) * \mathrm{Pm} - \mathrm{Cb}(\overline{\mathrm{L}}) \qquad (10)$$

Onde:

MC - Contribution margin (R$/ha);

$\overline{Y}(\overline{L})$ - Production Function corrected by UC_H;

Pm - Average price of the bean kg (R$);

$Cb(\overline{L})$ - Function of the relationship between pumping cost and depth applied.

RESULTS AND DISCUSSION

According to the ABNT NBR 14244 (1998) procedure, the equipment evaluated showed a 95% uniformity coefficient value with new assemblies of PVR-emitter.

Following the methodology based on the head pressure distribution assemblies after 8000h of use, the value of uniformity coefficient by using the mean deviation of all slides in all four positions studied was 89.89%. With this, we have a reduction of 5.11% in UC_H after 8000h of use of the equipment.

With the values of the uniformity coefficients was possible to plot the bean crop yield curves adjusted by the uniformity coefficient in two different situations of the equipment in the first, with the new equipment and CUC = 95% and the second after 8000h of use with CUC = 89.89%, as shown in Figure 2.

Using Equation 9, the depths that maximize crop yield and corresponded to 345.80mm 349.97mm and their productivities (Equation 8) were 2611.27 kg / ha and 2815.16 kg / ha for the uniformity coefficients 89.89 % and 95%, respectively. Therefore, the difference between the yields amounted to 203.89 kg / ha.

For the total consumption of electricity for pumping water was considered the value of 0,43kWh / m³, estimated in other test in this same central pivot. The cost of energy used has been set based on the current electricity tariff in the state of Minas Gerais, considering the operating time of the equipment as 21h / day, 9 hours per night irrigating with 80% of discount, and 12 hours with conventional rate, thereby generating values of R $ 376.72 / ha and R $ 370,00 / ha for the two different coefficients of uniformity.

The contribution margin values were found at $ 6407.81 / ha for UC_H 95% and R $ 5922.27 / ha for UC_H 89.89%, the bean fixed at kg R $ 2.41.

Thus, the difference in contribution margin to the variation of uniformity coefficient for the area in question corresponds to 59.6 ha, is in the order of R $ 28,938.18.

These results show that in one crop, producer decreases its contribution margin by approximately R $ 30,000.00 due to the variation of the uniformity coefficient caused by wear of the PVR-emitter.

It is important to note that the maximum contribution margin does not necessarily occur with the depth which maximizes the production, where these correspond to 343.71mm depth for CUC and 89.89% to 347.89 CUC 95%, net revenue values of R$ 5954.95 and R$ 6436.70 respectively, as shown in Figure 3. For this case, as the cost of pumping increased by a much higher proportion than the productivity of the depth which maximizes production, the use of maximum depth does not provide the greatest net revenue.

CONCLUSION

The analysis of the influence of the variation of the uniformity coefficient on the bean production curve allowed us to show the economic impact associated with the production costs and consequently the profit of the rural producer. With this, it is essential to periodically monitor the irrigation equipments, as well as all its components to guarantee greater efficiency and profitability in production.

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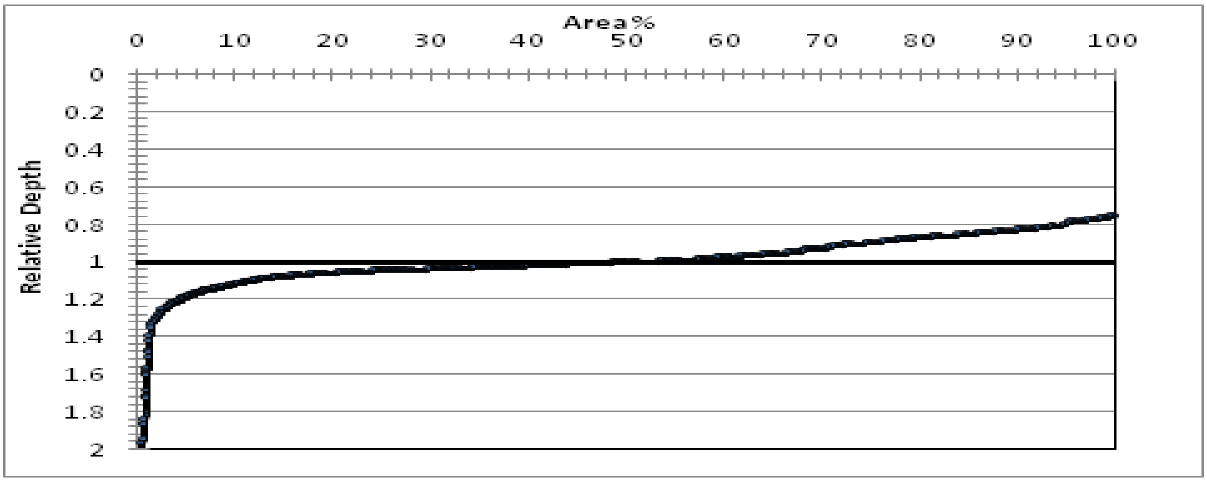

FIGURE 1. Depth Normal Distribution

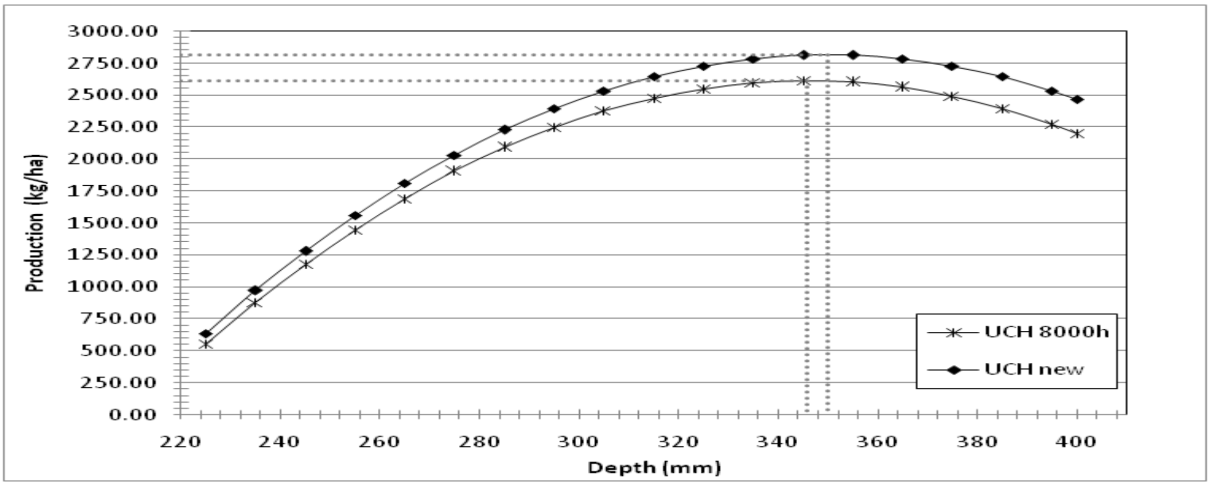

FIGURE 2. Production Function adjusted by uniformity coefficients

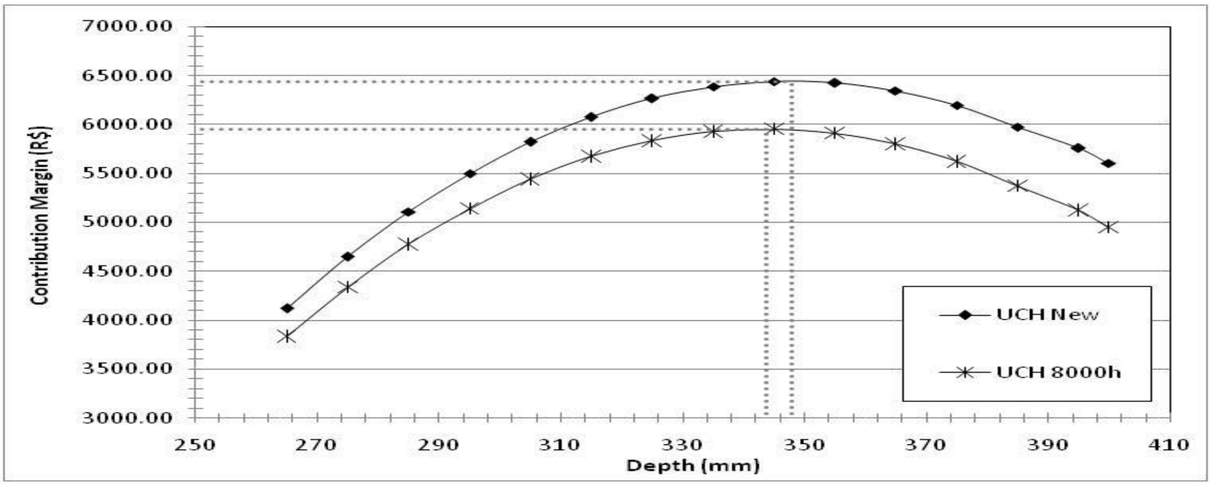

FIGURE 3. Contribution Margin adjusted by uniformity coefficients