Influence of lettuce as cover crop of the soil on sprinkler irrigation uniformity and parameters of efficiency

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ABSTRACT

The effect of lettuce as cover crop was evaluated on sprinkler irrigation uniformity and parameters of efficiency. The experiment was carried out in field at the Universidade do Oeste Paulista, in Presidente Prudente, São Paulo, Brazil, from August to October, 2006. One treatment was performed on bare soil and the other using lettuce cultivar Vera as cover crop, at the end of the cycle. The average water depth, application rate, uniformity of distribution coefficient, Christiansen uniformity coefficient, Hawaiian uniformity coefficient, as well as the statistical uniformity coefficient were evaluated. The following plant spacing were simulated: 12 x 12, 12 x 18, and 18 x 18 m. The highest water depth retained with lettuce crop cover, at the end of the cycle was 2.4 mm, applied when sprinklers were spaced at 12 x 12 m. The same occurred in the application rate with an average reduction of 43%. When the overlapping was performed, the crop cover did not influence the parameters of efficiency and uniformity, assuring the distribution of the irrigation depth. Neither treatment reached the expected rate concerning the water depth average or the application rate in the spaces. The treatment using cover crop presented the lowest value, with a water depth average below the intended amount. Therefore, the lettuce as cover crop promotes the reduction of applied water depth. Consequently, the irrigation time has to be increased to assure the expected water depth.

Keywords: *Lactuca sativa* L., irrigation assessment, irrigation management.

RESUMO

Influência da cobertura vegetal com alface sobre os parâmetros de eficiência e uniformidade da aspersão

O efeito da cobertura vegetal promovido pela alface foi avaliado nos parâmetros de eficiência e uniformidade da irrigação por aspersão. O experimento foi instalado em campo da Universidade do Oeste Paulista, em Presidente Prudente-SP, de agosto a outubro de 2006, sendo um tratamento com solo nu, sem cobertura vegetal, e outro tratamento com solo com cobertura vegetal (alface cultivar Vera no final do ciclo). Foram avaliados a lâmina média aplicada, intensidade de aplicação, coeficiente de uniformidade de distribuição, coeficiente de uniformidade de Christiansen, coeficiente de uniformidade havaiano e coeficiente de uniformidade estatístico. Foram simulados os espaçamentos de 12 x 12, 12 x 18 e 18 x 18 m. A maior lâmina retida pela cobertura vegetal com alface ao final do ciclo foi de 2,4 mm da lâmina aplicada, quando os aspersores estavam no espaçamento 12 x 12 m. O mesmo espaçamento promoveu uma redução média de 43% na intensidade de aplicação. Quando realizadas as sobreposições, a cobertura vegetal não promoveu diferenças nos parâmetros de eficiência e uniformidade, garantindo a distribuição da lâmina de irrigação. Para a lâmina média e a intensidade de aplicação nos espaçamentos, nenhum dos tratamentos alcançou o valor esperado, sendo que o tratamento com cobertura vegetal apresentou o menor valor, com uma lâmina aplicada abaixo da pretendida. Portanto, a cobertura vegetal com alface promove redução na lâmina aplicada, sendo necessário aumentar o tempo de irrigação para garantir a lâmina desejada.

Palavras-chave: *Lactuca sativa* L., avaliação da irrigação, manejo da irrigação.

Lettuce (*Lactuca sativa* L.) is one of the most consumed fresh vegetables in Brazil. Owing to its easily perishable condition and low resistance to transport, it is cultivated near the large consumer centers called "green belts" (Silva *et al.*, 2000). In Brazil the major production of lettuce is concentrated in São Paulo State, where summer and winter cultivars are planted round the year using an irrigation system (Andrade

Júnior *et al.*, 1992). The cultivar Vera is widely used with harvests performed between 50 and 70 days after the sowing (Trani *et al.*, 2005).

In modern agriculture, irrigation equipment has become outstanding due to the latest technological developments both at the industries which have been their producers as well as in terms of the agronomic knowledge regarding the correlation water-soil-plant. Concerning

the sprinkler irrigation, the system must be evaluated after the project implantation in order to determine whether its performance attends to the pre established planning, analyze the possible demanded adjustments to improve its performance as well as assess the quality of maintenance and the managing of the system.

In order to obtain an efficient irrigation it is necessary to use the

correct amount of water, as pre set by the project, in a uniform application on the area. According to Silva *et al.* (2006), it is essential to analyze the spatial distribution of the water applied on irrigated areas to implement the most adequate strategies for the irrigation managing.

Once the sprinklers apply water in a circular form, overlapping must be used to obtain satisfactory uniformity (Frizzone & Botrel, 1996; Pereira, 2003). In the conventional sprinkler system the most used plant spaces are 12 x 12, 12 x 18, 12 x 24, 18 x 18, 18 x 24, 18 x 30, 24 x 24, 24 x 30, 30 x 30, chosen according to each kind of sprinkler. (Bernardo *et al.*, 2005). According to Mateos (2006), the use of sprinkler irrigation performance parameters by using a grading sampling and scenario simulation represents a good performance estimate in total area.

It is common to express the water distribution uniformity in an irrigation system by a uniformity of distribution coefficient which shows the variability of the water depth applied on the soil (Brennan, 2008). The lack of uniformity in the water application makes some parts of the irrigated area become soaked whereas others remain under irrigated (Silva, 2006; Brennan, 2007). The efficiency measures quantify the quality of the irrigation physically and depend on the uniformity of the water application and the managing of the system. Several authors have used these measures to assess the water distribution in the sprinkler irrigation systems. (Rezende *et al.*, 1998; Rodrigues *et al.*, 2001; Paz *et al.*, 2002; Freitas *et al.*, 2003; Drumond *et al.*, 2006; Silva, 2006; Kara *et al.*, 2008).

Christiansen (1942) was the first to propose a coefficient to establish the water distribution uniformity in irrigation systems. The author used the mean absolute deviation to express the water depth dispersion. According to Frizzone (1992) the CUC (Christiansen uniformity coefficient) has been the simplest and mostly used. It expresses the variability of the water depths on the soil surface and is mainly influenced by the sprinklers spacing, wind speed and operating pressure.

Hart (1961) proposes a uniformity coefficient (Hawaiian Uniformity Coefficient (HUC)) which also incorporates the standard deviation. The Sugar Cane Association of Hawaii (HSPA) sponsored the development of such coefficient. Wilcox & Swailes (1947) proposed another coefficient denominated statistical uniformity (SUC), which uses the standard deviation as dispersion means.

According to Frizzone & Botrel (1996) and Rezende *et al.* (1998) ABNT recommends the analyses of water distribution through the uniformity in the portion of the irrigated area with less water. Thus, the UDC (The Uniformity of Distribution Coefficient) is used to relate the fourth part of the total irrigated area with less water to the average water depth. A UDC is frequently used to indicate the problems in the irrigation water distribution. A low value can indicate excessive loss of water due to deep percolation in case the applied water depth corresponds to the intended water depth. High uniformity rates are related to smaller spaces between sprinklers. Paz *et al.* (2002) recommended a UDC average value of 80% for sprinkler irrigation. Frizzone & Botrel (1996) and Zocoller (1999) recommended the average values of 82% to 88% for CUC and 70% to 80% for UDC, as adequate for cultures whose radicular system explores the first 0,40 m of the soil, basically.

The objective of this experiment was to evaluate the effect of lettuce as cover crop by the foliar interception of the irrigation water depths on the efficiency and the sprinkler irrigation uniformity at the moment of irrigation through the parameters of the average water depth, the application rate, uniformity of distribution coefficient, Christiansen and Hawaiian uniformity coefficients and statistical uniformity coefficient.

MATERIAL AND METHODS

The research was installed in the experimental area of UNOESTE in Presidente Prudente, São Paulo State (22º07'30''S; 51º26'00''; 430 m of altitude), from August to October, 2006. A sprinkler system was installed with Agropolo NY-30 sprinkler, nozzles of 6.20 x 4.60 mm, operating pressure of 245 kPa at the bottom of the ascension pipeline, flow rate of 2430 L h^{-1} and jet inclination angle of 30º and ascension pipeline of 1m, values defined in the project. The lateral and main pipelines of PVC, were installed with quick couplers, spaces of 12 m, flow rate of 60 mca (PN 60; 588 kPa) and diameter of 50 mm. Two treatments with 10 replications were tested in the field, in the same area, in two distinctive periods; 1) bare soil without cover crop before the transplantation and 2) soil with lettuce (cultivar Vera) as cover crop, at the end of the cycle, 50 days after the transplantation, directly in the seedbeds spaced 30 x 30 cm reaching the maximum foliar area.

The test consisted of the installation of 80 pluviometers with 10 cm of diameter (78.54 cm²) displayed in a net arrangement, 1.5 m x 1.5 m around the individual sprinkler, being the first collectors of the first row and column placed on half the space (75 cm). Frizzone & Dourado Neto (2003) recommend the use of the collectors with a minimum area of 50 cm² leading to a minimum of 8 cm of diameter. The collectors were installed under the culture dossel at 2 cm over the soil to enable catching the non intercepted irrigation depth by the foliar area of the culture. The volumes were obtained directly from the collectors at the end of the test using a glass test tube of 25 mL graded in 0.5 mL. This group of collectors represented the upper left side square within the sprinkled area. The values were established according to the methodology of Frizzone (1992) and the American Society of Agricultural Engineering (1989) joining 289 collectors. The test lasted 15 minutes. The speed and wind direction were registered for each experiment (Table 1).

To evaluate the influence of the sprinkler irrigation depth performed by the foliar interception of the culture, we determined: water depth average applied (Equation 1); application rate (Equation 2); uniformity of distribution

Table 1. Date and wind characterization for each replication (test) conducted between 9:00 am to 9:15 am (data e caracterização do vento para cada repetição (ensaio) realizado no período das 9:00 às 9:15 horas). Presidente Prudente, UNOESTE, 2006.

Treatments	Replication	Date	Speed of the wind (km h⁻¹)	Direction of the wind (⁰NV)
Without lettuce cover crop	1	14/08/06	16	60
	2	15/08/06	14	50
	3	16/08/06	16	40
	4	17/08/06	9	200
	5	18/08/06	17	132
	6	19/08/06	11	219
	7	20/08/06	13	212
	8	21/08/06	14	200
	9	22/08/06	16	100
	10	23/08/06	11	100
With lettuce cover crop	1	18/10/06	21	120
	2	19/10/06	17	110
	3	20/10/06	16	122
	4	21/10/06	20	90
	5	22/10/06	15	110
	6	23/10/06	18	100
	7	24/10/06	22	120
	8	25/10/06	13	60
	9	26/10/06	14	50
	10	27/10/06	9	40

coefficient (Equation 3); Christiansen uniformity coefficient (Equation 4); Hawaiian uniformity coefficient (Equation 5) and statistical uniformity coefficient (Equation 6) according to the methodologies described by Christiansen (1942), Wilcox & Swailes (1947), Hart (1961) and Frizzone (1992).

In which: ym= water depth average (mm); n= number of collectors (dimensionless); Xi= water depth collected in the pluviometer i (mm); Ia= application rate (mm h⁻¹); Q= flow (L h⁻¹); S= area (m²); UDC= uniformity of distribution coefficient (%); y_{25}= average of 25% of the smallest depths collected (mm); CUC – Christiansen uniformity coefficient (%); HUC – f Hawaiian uniformity coefficient (%); s – standard deviation; SUC – statistical uniformity coefficient (%).

After collecting the volumes in the field for both treatments, the program Catch 3D was used (Allen, 1992) to simulate the sprinklers' performance in spacing of 12 x 12m; 12 x 18m and 18 x 18m, recommended by the manufacturer for the working pressure of 245 kPa. This program offers the evaluation parameters for the sprinkler individually and allows the spacing simulation with

its respective evaluation parameters and with the graphic distribution of the irrigation depth.

The results were analyzed statistically with the Sisvar program by using the test of Tukey at 5% of significance to determine the best performances in each treatment.

RESULTS AND DISCUSSION

With the collected data we designed the graphic distribution of the water depths average without cover crop for the individual sprinkler (Figure 1). The values of the the sprinkler's individual test and of the space simulation were then calculated (Table 2). The average water depths expected under the test conditions were 1.0 mm for the individual sprinkler and 5.6 mm, 3.7 mm and 2.5 mm for the spaces 12 x 12 m, 12 x 18 m and 18 x 18 m, respectively.

The high wind speed during the experiment did not permit to reach the expected water depths (Table 1), from 9 km h⁻¹ (2.50 m s⁻¹) to 17 km h⁻¹ (4.72 m s⁻¹) for the treatment without cover crop and from 9 km h⁻¹ (2.50 m s⁻¹) to 22 km h⁻¹ (6.22 m s⁻¹) with treatment with cover crop. This is a typical climatic characteristic in the region of Presidente Prudente, with strong and dry winds which increase losses by drift and evaporation during the irrigation period.

The cover crop interfered and reduced the evaluation parameters for individual sprinklers (Table 2). According to Alves *et al.* (2001) the interception of water through the cover crop has been studied by different authors, mainly regarding forestal ecosystems and large field perennial cultures. However, there are few studies on annual cultures published.

The water depth average observed with the presence of cover crop represented 44% of the water depth average without cover crop. The treatment without cover crop presented a water depth average (ym) statistically equal to the expected water depth whereas the treatment with cover crop did not present the expected water depth of 1.0 mm (Figure 2A). Such fact leads

Equations

$$ym = \left(\frac{\sum_{i=1}^{n} Xi}{n} \right) \quad (1)$$

$$Ia = \left(\frac{Q}{S} \right) \quad (2)$$

$$UDC = \frac{y_{25}}{ym} \cdot 100 \quad (3)$$

$$CUC = 100 \cdot \left(\frac{\sum_{i=1}^{n} |xi - ym|}{n \cdot ym} \right) \quad (4)$$

$$HUC = \left(1 - \sqrt{\frac{2}{\pi} \cdot \frac{s}{ym}} \right) \cdot 100 \quad (5)$$

$$SUC = \left(1 - \frac{s}{ym} \right) \cdot 100 \quad (6)$$

Table 2. Sprinkler AGROPOLO NY-30 evaluation parameters, for the treatment without cover crop (1) and with cover crop (2) (parâmetros de avaliação do aspersor AGROPOLO NY-30, para o tratamento sem cobertura vegetal (1) e o tratamento com cobertura vegetal (2)). Presidente Prudente, UNOESTE, 2006.

Treatment		Ym (mm)	Ia (mm h⁻¹)	UDC (%)	CUC (%)	HUC (%)	SUC (%)
Individual sprinkler	1	0.9 a	3.7 a	28 a	59 a	57 a	46 a
	2	0.4 b	1.6 b	15 b	40 b	45 b	31 b
	CV(%)	17.0	17.0	28.1	14.7	11.93	20.0
12x12 m	1	4.2 a	16.6 a	79 a	87 a	86 a	82 a
	2	1.8 b	7.2 b	78 a	87 a	83 a	79 a
	CV(%)	18.0	18.0	10.1	5.69	6.1	7.9
12x18 m	1	2.8 a	11.1 a	73 a	81 a	81 a	76 a
	2	1.2 b	4.8 b	68 a	77 a	77 a	71 a
	CV(%)	18.0	18.1	13.7	10.4	8.7	11.8
18x18 m	1	1.9 a	7.4 a	66 a	76 a	75 a	69 a
	2	0.8 b	3.2 b	62 a	74 a	73 a	66 a
	CV(%)	18.0	18.0	15.1	11.2	10.0	13.6

Means followed by the same letter in the column did not differ from each other, Tukey test, p<0.05 (médias seguidas de mesma letra nas colunas não diferem significativamente entre si, teste de Tukey, p<0,05). Ym= average size depth applied; Ia= instantaneous application rate; UDC= uniformity of distribution coefficient; CUC= Christiansen uniformity coefficient; HUC= Hawaiian uniformity coefficient and SUC= statistical uniformity coefficient (Ym= lâmina média aplicada; Ia= intensidade de aplicação, UDC= coeficiente de uniformidade de distribuição; CUC= coeficiente de uniformidade de Christiansen; CUH= coeficiente de uniformidade havaiano e CUE= coeficiente de uniformidade estatístico).

to a hydric deficiency in the culture, considering that the main objective of the irrigation is to apply the necessary water depth to the radicular zone of the plant for its full development, according to Kara *et al.* (2008).

Regarding the instantaneous application parameter, the treatment with cover crop represented 43% of the value observed in the treatment without cover crop. For the other parameters, the interference in the treatment with cover crop was smaller in spite of presenting the same tendency, whose values were 54% of CUD, 68% of CUC, 79% of HUC and 67% of SUC in relation to the treatment without the cover crop (Table 2).

The cover crop interfered with the water distribution in the area due to the fact that the height of the water applied from the sprinkler was above the height of the adult plant thus preventing its penetration in the soil, as the water was retained by the leaves.

In the simulations with overlapping, only the water depth and the application rate showed significant differences. The values obtained in the treatment with cover crop led to 43% of the water depth, except for the spacing of 18 x 18 m, which had 50% of the water depth applied compared to the treatment without cover crop. The treatment with cover crop promoted 43% of the instantaneous application rate in all the simulations compared to the treatment without cover crop (Table 2). There was no significant difference for the other parameters, which indicates that the right overlapping eliminated the lack of uniformity in the irrigation promoted by the cover crop.
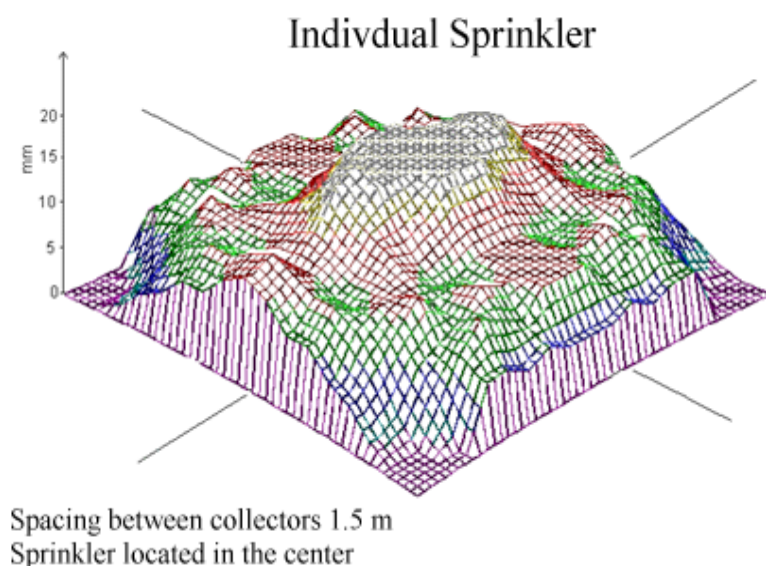
Figure 1. Depth distribution for individual sprinkler AGROPOLO NY-30 without cover crop (distribuição das lâminas para o aspersor AGROPOLO NY-30 individual sem cobertura vegetal). Presidente Prudente, UNOESTE, 2006.
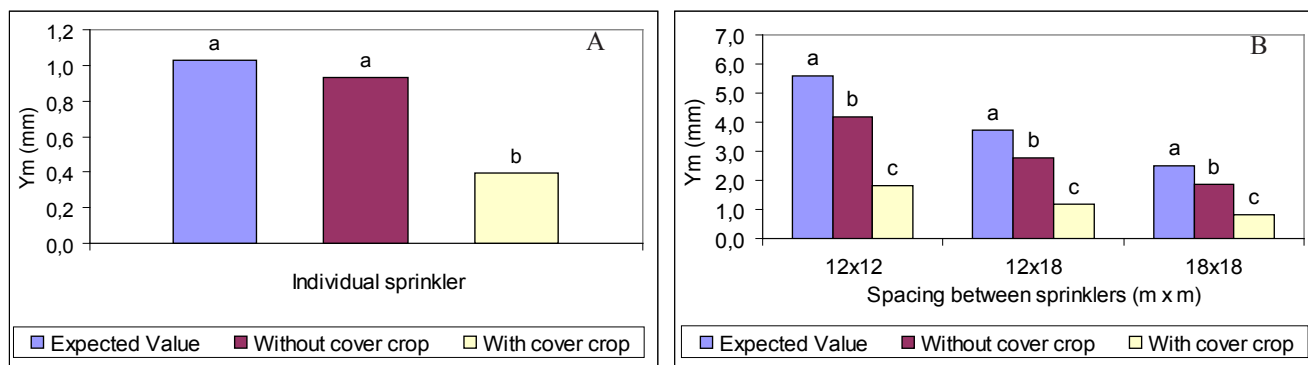
Figure 2. Average water depth observed in the test for the sprinkler AGROPOLO NY-30. A) Individual sprinkler and spacing B) 12 x 12 m, 12 x 18 m e 18 x 18 m (lâminas médias observadas no ensaio para o aspersor AGROPOLO NY-30. A) Aspersor individual e B) espaçamentos 12 x 12 m, 12 x 18 m e 18 x 18 m). Presidente Prudente, UNOESTE, 2006.

After evaluating the sprinkler irrigation uniformity and efficiency in different spacing dispositions using CATCH-3D, Kara *et al.* (2008) realized that the increase in spacings causes a fall in the uniformity coefficient. Therefore, they consider the tests in field and simulations as important tools to select the adequate spacing and assure acceptable uniformity values. Regarding the situation tested, the uniformity values were only acceptable for the spacing 12 x 12 m: UDC between 70% and 80% and CUC between 82% and 88% (Frizzone & Botrel, 1996; Zocoller, 1999; Paz *et al.*, 2002; Kara *et al., 2008*). In the other spacing (12 x 18 m e 18 x

18 m) occurred a lack of uniformity in the irrigation (Table 2).

When analyzing the average water depth in the spacing (Figure 2B) and the instantaneous application rate in the spacing (Figure 3), neither treatment reached the expected value. The treatment with cover crop presented the lower value for both parameters with a water depth below the expected. At the end of the cycle, the cover crop retained 2.4 mm; 1.6 mm and 1.1 mm of the water depth applied when the sprinklers were in spacing of 12 x 12 m; 12 x 18m and 18 x 18m, respectively.

Therefore, we can conclude that the cover crop reduced the uniformity

in the water depth applied to the soil, representing an average of 43% of the water depth applied without cover crop, except for the spacing of 18 x 18 m, which had 50% of the water depth applied compared to the treatment without cover crop, interfering with the adequate management of the irrigation. Consequently, it is essential to increase the irrigation period in order to assure the adequate irrigation depth. Actually, the need for such practice is also supported by a second irrigation, which is commonly used in other horticultural crops in Presidente Prudente.

The cover crop caused a reduced value of the application rate, leading to an average of 43% when compared to the treatment without cover crop. The cover crop did not promote significant differences in the uniformity parameters when the spacing used was 12 x 12 m between sprinklers and lines, allowing a balanced irrigation depth distribution. Eventually there was a fall in the sprinklers' performance in the other spacing.

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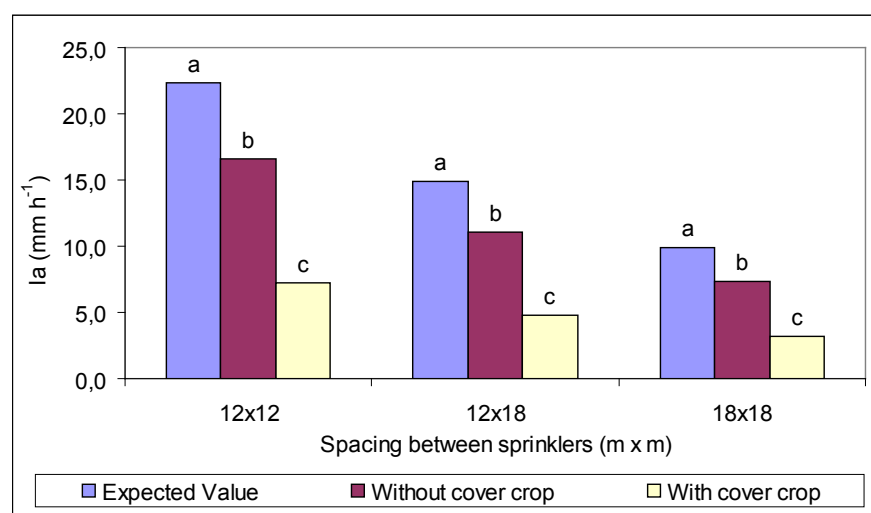
Figure 3. Instantaneous application rate observed in the sprinkler's test. AGROPOLO NY-30 for spacing 12 x 12 m, 12 x 18 m e 18 x 18 m (intensidades de aplicação observadas no ensaio para o aspersor AGROPOLO NY-30 nos espaçamentos 12 x 12 m, 12 x 18 m e 18 x 18 m). Presidente Prudente, UNOESTE, 2006.

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