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ECONOMIC FEASIBILITY OF IRRIGATION SYSTEMS IN BROCCOLI CROP

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ABSTRACT: This study aimed to analyze the economic feasibility of different irrigation systems in broccoli cropping, in Dourados - MS, Brazil. Initially, irrigation was performed using different systems (surface drip, subsurface drip, micro sprinkler, Santeno® and conventional sprinkler). Both yield of commercial inflorescence (CIY) and applied water depth (AWD) were determined during trial. Economic feasibility was analyzed through estimates of acquisition cost (AC), total annual cost (TAC), gross revenue (GR), net revenue (NR), benefit-cost rate (BCR), return rate (RR) and return time (RT). Subsurface drip irrigation was the most feasible in addition to using the second lowest AWD (170.3 mm) compared to the other systems. The values of CIY, AC, RR, BCR and TAC obtained by this system were 25.3 t ha^{-1}, R $ 8,884.8 ha^{-1}, R $ 65,446.9 ha^{-1} yr^{-1}, 7.3 and 6.32%, respectively.

KEY WORDS: economic indicators, vegetables, irrigation.

VIABILIDADE ECONÔMICA DE SISTEMAS DE IRRIGAÇÃO NO CULTIVO DE BRÓCOLIS DE CABEÇA

RESUMO: O objetivo deste trabalho foi analisar a viabilidade econômica de sistemas de irrigação no cultivo de brócolis de cabeça, para a região de Dourados-MS. Inicialmente, foi realizado o cultivo de brócolis de cabeça irrigado por diferentes sistemas de irrigação (gotejamento superficial, gotejamento subsuperficial, microaspersão, Santeno® e aspersão convencional). No período experimental, determinaram-se a produtividade comercial de inflorescência (PCI) e a lâmina de água aplicada (LAA). Para a análise da viabilidade econômica foram calculados o custo de aquisição (CA), o custo total anual (CTA), a receita bruta (RB), a receita liquida (RL), a relação benefício custo (B/C), a taxa de retorno (TAR) e o tempo de retorno (TER). O sistema de irrigação por gotejamento subsuperficial apresentou maior viabilidade econômica, além de utilizar a segunda menor LAA (170,3 mm) em relação aos demais sistemas avaliados. Os valores de PCI, CA, RL, B/C e TAR obtidos por esse sistema foram de 25,3 t ha^{-1}, R$ 8.884,8 ha^{-1}, R$ 65.446,9 ha^{-1} ano^{-1}, 7,3 e 6,32 %, respectivamente.

PALAVRAS-CHAVE: indicadores econômicos, hortaliça, irrigação.

INTRODUCTION

For broccoli (*Brassica oleracea* var. *Italica*), irrigation is essential and a proper irrigation system is required to reach high yields, under a management that supplies the exact amount of water

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required by plants, keeping soil moisture at desired levels, as well as providing water and energy savings (AYAS et al., 2011; KUMAR & SENSEBA, 2008).

Broccoli cultivation is considerably new in Brazil (CECÍLIO FILHO et al., 2012); thus, studies on most suitable irrigation systems for such crop are still needed. Literature studies highlight drip irrigation as most rational regarding water use, besides providing nutrients through fertigation practice (DOUH et al., 2013; van der KOOIJA et al., 2013; BORSSOI et al., 2012). However, all methods and systems such as surface drip irrigation (ERDEM et al., 2010), subsurface drip irrigation (DOUH et al., 2013), micro sprinkler (KUMAR & SENSEBA, 2008), Santeno® (GEISENHOFF et al., 2015), furrow irrigation (KUMAR & SENSEBA, 2008) and conventional sprinkling (LALLA et al., 2010) can be used for such vegetable cultivation.

Choosing the most appropriate system should consider operational performance and economic viability concurrently (LIMA JUNIOR et al., 2011; LIMA JUNIOR et al., 2012). High operational performance generally provides higher yields; however, economic feasibility studies are essential to select a proper technology (MARQUES & FRIZZONE, 2005).

KUMAR & SENSEBA (2008) evaluated irrigated broccoli crops under three different systems (surface drip, micro sprinkler and furrows) and observed that surface drip promoted the highest production costs. The authors explained that such high cost was due to implementation; however, net revenue between sprayer and surface drip were similar and larger compared to net revenues of furrow system.

Considering the implementation costs and crop yield provided by each irrigation system, selecting the most suitable system could directly influence production economic viability. On the other hand, higher yields may not correspond to higher net sales due to the complex nature of crop response to irrigation, climate variability and fluctuations in economic conditions (LIMA JUNIOR et al., 2014; LIMA JUNIOR et al., 2011). Therefore, economic evaluations of irrigations systems may indicate which one increases yields and has a good economic performance concurrently, as well as having a rational use of irrigation water.

Economic feasibility studies for broccoli involving different irrigation systems cannot be found in literature. Based on the above, this study aimed to analyze the economic feasibility of irrigation systems in broccoli crops grown in the county of Dourados - MS, Brazil.

MATERIAL AND METHODS

Crop handling

The experiment was carried out at the experimental irrigation area in the College of Agricultural Sciences (FCA), which belongs to the *Universidade Federal da Grande Dourados* – UFGD (Federal University of Great Dourados - UFGD), located in the city of Dourados, Mato Grosso do Sul State, Brazil (22° 13' 16" south latitude and 54° 48' 20" west longitude).

On June 13 of 2013, broccoli seedlings were transplanted into a prepared area at a spacing of 0.5 x 1.0 m, in a total of 20,000 plants ha^{-1}. Each irrigation system supplied a block of 80 plants, which was divided into four plots with 20 plants. These 20 plants consisted of four rows containing five plants. Two rows from the outer edges were set apart for edge effect, as well as the first and last plant within central rows; thus, six plants composed experimental units.

Drip tapes performed drip irrigation using one self-compensating emitter for each plant. Nominal flow rate was of 1.48 L h^{-1} at an operating pressure of 99.1 kPa. Surface and subsurface drip irrigation used the same configuration; however, in subsurface dripping, tapes were installed about 0.05 m below ground surface.

Micro sprinkler system consisted of emitters with nominal flow rate of 44.9 L h^{-1} at a pressure of 99.1kPa; they have been installed with 1.5 m spacing between rows and on the row itself, providing wet area overlapping between them.

Santeno® system was composed of Santeno® tape type I. This tape has the following characteristics: internal diameter of 28 mm, wall thickness of 0.24 mm and laser-perforated emitters with 0.3 mm of diameter. Emission points were spaced each 0.15 m, being composed of groups of four emitters. Ten-meter long rows were spaced apart by 3 m. A working pressure of 79.5 kPa was used, providing a nominal flow rate of 3.06 L h^{-1} at each emission point.

Conventional sprinkler was composed of sprinklers with nominal flow rate of 425.8 L h^{-1} at a working pressure of 197.2 kPa; they were spaced forming a square of 6 meters on the side.

The soil-water characteristic curve was determined to assist irrigation management. For that, deformed soil samples were sampled within a range of 0 to 0.2 m depth. Low-tension points (2, 4, 6 and 10 kPa) were determined in Haines funnel using saturated sample in hydraulic contact with a porous plate, maintaining the U-tube at a level somewhat higher than the sample. Meanwhile, high-tension points (33, 100, 500 and 1500 kPa) were determined in Richards extractor, and equation parameters were generated following the model proposed by van GENUCHTEN (1980).

Irrigation management was carried out with the aid of a battery of five tensiometers set at two plots of each block; among which, three of them (decision tensiometer) were set at a depth of 0.2 m and two (monitoring tensiometer) at 0.4 m depth.

The goal of the irrigation was to maintain soil moisture at field capacity (0.37 cm^3 cm^{-3}), which was obtained by water retention curve in the soil [eq. (1)] at 10 kPa. When two of the three decision tensiometers indicated a critical pressure (12 kPa) (VILLALOBOS-REYES et al., 2005), irrigations were held by applying 100% of the required water depth. Two monitoring tensiometers were used to control excess of irrigated water.

The applied water depth (AWD) during crop cycle was estimated by water retention curve in the soil [eq. (1)], considering the effective depth of root system (25 cm), as held by GEISENHOFF et al. (2015).

$$\theta_a = 0.2133 + \frac{0.3667}{[1 + (0.2906|\Psi m|^{1.7254})]^{0.4204}} \quad (1)$$

In which,

θ_a - current soil moisture with volumetric basis, cm^3 cm^{-3}, and

Ψm - water tension in the soil, kPa.

Manual harvesting was held on September 12, 2013 (92 days after transplanting). After harvesting, commercial inflorescence yield (CIY) was estimated based on mean fresh weight of inflorescences and spacing used (1.0 x 0.5 m).

Analysis of the economic viability

Economic evaluations consisted of determining the acquisition costs (AC), total annual cost (TAC), gross revenue (GR), net revenue (NR), benefit-cost rate (BCR), return rate (RR) and return time (RT) for each 1.0-ha broccoli crop irrigated by surface drip irrigation, subsurface drip irrigation, micro sprinkler, Santeno® and conventional sprinkling. Price searching of equipment and operational costs was held on February 3, 2015.

Total costs were divided into fixed and variable costs. The first involved costs with pumping, pipes, fittings, gauges, filters, valves, irrigation and automation equipment. The values were surveyed in companies with expertise in marketing, designing and implementing of irrigation systems.

The yearly fixed costs were estimated based on acquisition costs and capital recovery factor (CRF), which is responsible for repaying capital investments [eq. (2)]. Pumping and irrigation systems had their CRF calculated separately, taking into consideration market interest rate per year (11%) and their operating lifespan [eq. (3)].

We used a 25-year operating lifespan for the pumping system (KUMAR & SENSEBA, 2008); yet for dripping system (surface and subsurface), micro sprinkler and conventional sprinkler, we considered an operating lifespan of 15 years (MARQUES & COELHO, 2003). And Santeno® system was accounted for 8 years, being set according to the manufacturer's catalog.

$$FCA = AC \times CRF \tag{2}$$

$$CRF = \frac{i\,(i+1)^{OL}}{(i+1)^{OL} - 1} \tag{3}$$

In which,

FAC - fixed annual cost, in R$ ha^{-1} yr^{-1};

AC - system acquisition cost, in R$ ha^{-1};

CRF - capital recovery factor, in decimal;

i - interest rate, in %, and

OL - operating lifespan, in years.

Variable costs were estimated considering inputs, services, electricity, maintenance and labor required during the entire crop cycle [eq. (4)].

$$AVC = EC + SMaC + LC + IC + SC \tag{4}$$

In which,

AVC - annual variable cost, in R$ ha^{-1} yr^{-1};

EC - electricity cost, in R$ ha^{-1} yr^{-1};

SMaC - system maintenance cost, in R$ ha^{-1} yr^{-1};

LC - labor cost, in R$ ha^{-1} yr^{-1};

IC - input costs, in R$ ha^{-1} yr^{-1}, and

SC – service costs, in R$ ha^{-1} yr^{-1}.

Electricity cost was estimated for each system based on gross water depth applied, pump working pressure, and power tariff [eq. (5)]. Low-tension applications were calculated using a power low-voltage tariff (R$ 0.19 kW^{-1} h^{-1}), as proposed by the *Empresa Energética do Mato Grosso do Sul – Enersul* (Light and Power Company of Mato Grosso do Sul State), which suggests a conventional tariff mode within a subgroup of public services in irrigation (green flag).

$$EC = \frac{10\ I\ Hm\ \gamma}{3.6\ 10^{6}\ \eta}\ Tc \tag{5}$$

In which,

I - gross irrigation depth demanded by crop, in mm;

Hm - system working pressure, in m of water;

γ - water specific weight, in N m^{-3};

η - pump set efficiency, in decimal, and

Tc - electric power consumption tariff, in R$ kWh^{-1}.

Pumping working pressures were 20.1; 20.1; 36.0; 14.9 and 53.5 m of water for surface and subsurface drip irrigation, micro sprinkler, Santeno® and conventional sprinkler, respectively.

System maintenance costs (SMaC) considered a percentage of initial costs of each irrigation system [eq. (6)]. For surface and subsurface dripping, initial cost percentage was 4%. For Santeno® and micro sprinklers, it was 2.5%; and for conventional sprinkler, it was 2% (MAROUELLI & SILVA, 2011).

$$SMac = \frac{IC \times AC}{100} \tag{6}$$

In which,

IC - initial cost percentage, in %.

Labor costs were calculated using workers' wages, number of employees per hectare, labor charges and months worked per year [eq. (7)]. Minimum wage was set at R$ 785.00, as indicated by the *Federação da Agricultura e Pecuária de Mato Grosso do Sul - FAMASUL* (Farming and Livestock Federation of Mato Grosso do Sul State - FAMASUL) for rural workers. Labor rates are in accordance with national laws. Months worked were set at four (crop cultivation period). Number of employees in dripping systems (surface and subsurface) and in conventional sprinkler was of 0.2 man ha^{-1}. For Santeno® and micro sprinkler, it was 0.1 man ha^{-1} (MAROUELLI & SILVA, 2011).

$$LC = Wa \times \left(1 + \left(\frac{Va + CB + SS + SS_{CB}}{100}\right)\right) \times NE \times WM \tag{7}$$

In which,

Wa - wages, in R$ $month^{-1}$;

Va – vacation charges, in %;

CB – Christmas bonus, in %;

SS – social security, in %;

SS_{CB} – social security rate in CB, in %;

MW – months worked, and

NE - number of employees for irrigation management, men ha^{-1}.

Service costs involve crop implementation and management activities such as plowing, harrowing, fertilization, seedling growing, furrowing, transplanting, weeding, topdressing and harvesting. Yet input costs comprise expenditures with seeds, lime, fertilizer and pesticides. The total annual cost was then obtained by adding up fixed and variable costs [eq. (8)].

$$TAC = AFC + AVC \tag{8}$$

In which,

TAC - total annual cost, in R$ ha^{-1} yr^{-1}.

Gross revenue was estimated accounting crop yields in each irrigation system and price paid for broccoli [eq. (9)]. We used a price of R$ 3.0 per kg (local average price).

$$GR = Yb \times Pr \tag{9}$$

In which,

GR - gross revenue, R$ ha^{-1} yr^{-1};

Yb - broccoli productivity, kg ha^{-1} yr^{-1}, and

Pr - broccoli price, R$ kg^{-1}.

Given the above, net revenue was calculated by subtracting the gross revenue from the total annual cost [eq. (10)].

$$\mathrm{NR} = \mathrm{GR} - \mathrm{ATC} \tag{10}$$

In which,

NR - net revenue, in R$ ha^{-1} yr^{-1}.

Benefit-cost rate was estimated by the ratio between gross revenue and total annual cost [eq. (11)].

$$\mathrm{BCR} = \frac{\mathrm{GR}}{\mathrm{ATC}} \tag{11}$$

In which,

BCR – benefit-cost rate, decimal.

Return rate was determined by the ratio between total annual cost and net revenue [eq. (12)]; and return time was estimated by the ratio between acquisition costs and net revenue [eq. (13)].

$$\mathrm{RR} = \frac{\mathrm{NR}}{\mathrm{ATC}} \times 100 \tag{12}$$

$$\mathrm{RT} = \frac{\mathrm{AC}}{\mathrm{NR}} \tag{13}$$

In which,

RR – return rate, %, and

RT – return time, years.

RESULTS AND DISCUSSION

Regarding the CIY, irrigation systems followed the descending order of subsurface drip irrigation (25.3 t ha^{-1}), surface drip irrigation (24.5 t ha^{-1}), micro sprinkler (20.5 t ha^{-1}), conventional sprinkler (17.4 t ha^{-1}) and Santeno® (16.8 t ha^{-1}) (Table 1). Conversely, speaking of AWD, we observed a different trend in which the decreasing order was Santeno® (206.4 mm), conventional sprinkler (202.6 mm), micro sprinkler (180.0 mm), subsurface drip irrigation (170.3 mm) and surface drip irrigation (156.7 mm) (Table 1).

The highest yield of subsurface drip system was 50.2% higher than the lowest one found for Santeno® system, despite applying the largest water depth during crop. GEISENHOFF et al. (2015), analyzing broccoli crops under different irrigation systems (subsurface drip, surface drip, micro sprinkler, conventional sprinkler and Santeno®), observed that subsurface drip irrigation increased crop yields, as reported in this paper.

Based on field data, subsurface dripping was the most suitable for broccoli cultivation, once it provided high yields applying the second smallest water depth. Nevertheless, the choice for a specific irrigation system should consider agronomic, economic, and often, social factors (MAROUELLI & SILVA, 2011).

TABLE 1. Commercial inflorescence yield (CIY) and applied water depth (AWD) during broccoli growing season.

Irrigation systems	CIY (t ha^{-1})	AWD (mm)
Subsurface drip irrigation	25.3	170.3
Surface drip irrigation	24.5	156.7
Santeno®	16.8	206.4
Micro sprinkler	20.5	180.0
Conventional sprinkler	17.4	202.6

With respect to acquisition costs (AC), subsurface and surface drip systems showed the highest values (R$ 8,884.8 ha^{-1}). On the other hand, Santeno® showed the lowest one (R$ 4,939.9 ha^{-1}). Conventional sprinkler and micro sprinkler systems had AC values of R$ 6,450.1 ha^{-1} and R$ 7,688.7 ha^{-1}, respectively (Table 2). The largest values of subsurface and surface drip irrigation can be attributed to polyethylene pipe costs that are higher than PVC tubing (used in the other systems), besides the largest amount of pipes and settings made, since they used one emitter per plant.

The decreasing order for total annual costs (TAC) was subsurface and surface drip irrigation (R$ 10,363.1 and R$ 10,359.2 ha^{-1} yr^{-1}, respectively), conventional sprinkling (R$ 9,888.6 ha^{-1} yr^{-1}), micro sprinkler (R$ 9,649.9 ha^{-1} yr^{-1}) and Santeno® (R$ 9,368.7 ha^{-1} yr^{-1}) (Table 2).

TABLE 2. Acquisition costs (AC), total annual cost (TAC), gross revenue (GR) and net revenue (NR).

Irrigation systems	AC (R$ ha^{-1})	TAC	GR (R$ ha^{-1} yr^{-1})	NR
Subsurface drip irrigation	8,884.8	10,363.1	75,810.0	65,446.9
Superficial drip irrigation	8,884.8	10,359.2	73,350.0	62,990.8
Santeno®	4,939.9	9,368.7	50,460.0	41,091.3
Micro sprinkler	7,688.7	9,649.9	61,560.0	51,910.1
Conventional sprinkler	6,450.1	9,888.6	52,140.0	42,251.4

Gross revenue (GR) and net revenue (NR) for subsurface drip irrigation was of R$ 75,810.0 ha^{-1} yr^{-1} and R$ 65,446.9 ha^{-1} yr^{-1}, respectively. The smallest RB (R$ 50,460.0 ha^{-1} yr^{-1}) and RL (R$ 41,091.3 ha^{-1} yr^{-1}) were observed for Santeno® system (Table 2).

Subsurface drip irrigation required major investment and had higher annual costs; however, its increased yields exceeded the other systems, proportioning thus the highest net revenue. Lower annual and acquisition costs were observed concurrently with lower yields in Satemo® system, resulting in lower net sales among the evaluated systems. The same tendency was observed by KUMAR & SENSEBA (2008), in which TAC was higher when plants were irrigated by surface drip. For NR, both drip irrigation resulted in higher values compared to the other systems, as observed by HANSON & MAY (2004), who compared surface drip and conventional sprinkler in tomato crops.

Feasibility analysis involves some economic indicators as benefit-cost rate (BCR), return rate (RR) and return time (RT). These indexes contribute to select the most suitable irrigation system for broccoli cultivation. Our study showed that all systems had BCR greater than one, highlighting that such yield increase was enough to reimburse irrigation expenses and provide an economic return (Table 3).

Subsurface drip showed higher BCR (7.3), being therefore the system of major benefits regarding implementation and management costs. In turn, conventional sprinkler promoted a lower BCR (5.3).

KUMAR & SENSABA (2008) observed a same trend for BCR (> 1) in broccoli under three different irrigation systems (surface drip, micro sprinkler and furrows); this fact can be attributed to crop high yields. FURLANETO et al. (2007) also observed that increasing yields derived from irrigation were enough to raise profits, with an increase of 13.4% in banana production compared to cultivations without irrigation, denoting the importance of irrigations in such crop.

RR is the return on investment in irrigation; thus, subsurface drip irrigation has increased efficiency of the applied investment, i.e. the capital invested generated a higher economic return. Regarding the RT (time required to recover an investment), the money invested in each system was compensated within one year (Table 3); so irrigated broccoli crops achieve economic return on the capital invested.

TABLE 3. Cost-benefit rate (BCR), return rate (RR) and return time (RT).

Irrigation systems	C/B (decimal)	RR (%)	RT (yrs.)
Subsurface drip irrigation	7.3	6.32	0.14
Surface drip irrigation	7.1	6.08	0.14
Santeno®	5.4	4.39	0.12
Micro sprinkler	6.4	5.38	0.15
Conventional sprinkler	5.3	4.27	0.15

CONCLUSIONS

Subsurface drip irrigation has most economic feasibility the other evaluated systems for broccoli cultivation in Dourados - MS, Brazil. This system had the highest yield, gross revenue and net revenue, being of 25.3 t ha^{-1}, R$ 75,810.0 ha^{-1} yr^{-1} and R$ 65,446.9 ha^{-1} yr^{-1}, respectively. Such values were achieved using the second smallest water depth applied during the growing season (170.3 mm) in relation to the treatments analyzed.

The acquisition costs of subsurface and surface drip irrigation, Santeno® micro sprinkler and conventional sprinkler were of 8,884.8; 8,884.8; 4,939.9; 7,688.7 and 6,450.1 R$ per ha, respectively. Economic viability indices showed that, among all treatments, subsurface drip irrigation had the best benefi-cost rate (7.3) and return rate (6.32%).

REFERENCES

AYAS, S.; ORTA, H.; YAZGAN, S. Deficit irrigation effects on broccoli (*Brassica oleracea* var. Monet) yield in unheated greenhouse condition. **Bulgarian Journal of Agricultural Science,** v.17, n.4, p.551-559, 2011.

BORSSOI, A.L.; VILAS BOAS, M.A.; REISDÖRFER, M.; HERNÁNDEZ, R.H.; FOLLADOR, F.A.C. Water application uniformity and fertigation in a dripping irrigation set. **Revista Engenharia Agrícola**, v.32, n.4, p.718-726, jun./ago. 2012.

CECÍLIO FILHO, A.B.; SCHIAVON JUNIOR, A.A.; CORTEZ, J.W.M. Produtividade e classificação de brócolis para indústria em função da adubação nitrogenada e potássica e dos espaçamentos entre plantas. **Horticultura Brasileira**, v.30, n.1, p.12-17, jan./mar. 2012.

DOUH, B.; BOUJELBEN, A.; KHILA, S.; BEL HAJ MGUIDICHE, A. Effect of subsurface drip irrigation system depth on soil water content distribution at different depths and different times after irrigation. **Larhyss Journal**, n.13, p.7-16, mar. 2013.

ERDEM, T.; ARLN, L.; ERDEM, Y.; POLAT, S.; DEVECI, M.; OKURSOY, H.; GÜLTAŞ, H. Yield and quality response of drip irrigate broccoli (*Brassica oleracea* L. var. *italica*) under different irrigation regimes, nitrogen applications and cultivation periods. **Agricultural Water Management,** v.97, n.5, p.681-688, may, 2010.

FURLANETO, F.P.B.; MARTINS, A.N.; CAMOLESI, M.R.; ESPERANCINI, M.S.T. Análise econômica de sistemas de produção de banana (*Musa* sp.), cv. Grande Naine, na região do Médio Paranapanema, estado de São Paulo. **Científica**, v.35, n.2, p.188-195, 2007.

GEISENHOFF, L.O.; OLIVEIRA, F.C.; BISCARO, G.A.; ALMEIDA A.C. dos S.; SCHWERZ, F. Produtividade do brócolis-de-cabeça sob diferentes sistemas de irrigação. **Revista Engenharia Agrícola**, v.35, n.5, p.863-874, set./out. 2015.

HANSON, B.; MAY, D. Effect of subsurface drip irrigation on processing tomato yield, water table depth, soil salinity, and profitability. **Agricultural Water Management**, v.68, n.1, p.1-7, Jul. 2004.

KUMAR, J.L.G.; SENSEBA, T. Yield, irrigation production efficiency and economic return of broccoli (*Brassica oleracea* var. italica) under different irrigation, methods and schedules. **Journal of Environmental Research and Development**, v.2, n. 4, p.513-522, abr./jun. 2008.

LALLA, J.G.; LAURA, V.A.; RODRIGUES, A.P.D.C.; SEABRA JÚNIOR, S.; SILVEIRA, D.S.; ZAGO, V.H.; DORNAS, M.F. Competição de cultivares de brócolos topo cabeça única em Campo Grande. **Horticultura Brasileira**, v.28, n.3, p.260-363, jul./set. 2010.

LIMA JUNIOR, J.A.; PEREIRA, G.M.; GEISENHOFF, L.O.; COSTA, G.G.; REIS, R. P.; OLIVEIRA, L.F.C. Avaliação econômica da produção de alface americana em função de lâminas de irrigação. **Ciência e Agrotecnologia**, v.35, n.2, p.392-398, mar./abr. 2011.

LIMA JUNIOR, J.A.; PEREIRA, G.M.; GEISENHOFF, L.O.; SILVA, W.G.; VILAS BOAS, R.C.; SOUZA, R.J. Desempenho de cultivares de cenoura em função da água no solo. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v.16, n.5, p.514-520, maio, 2012.

LIMA JUNIOR, J.A.; PEREIRA, G.M.; GEISENHOFF, L.O.; SILVA, W.G.; SOUZA, R.O.R.M.; VILAS BOAS, R.C. Economic viability of a drip irrigation system on carrot crop. **Revista de Ciências Agrárias Amazonian Journal of Agricultural and Environmental Science**. V. 57, n.1, p.15-21, jan./mar. 2014.

MAROUELLI, W.A.; SILVA, W.L.C. **Seleção de sistemas de irrigação para hortaliças**. Brasília: Embrapa, 2011. (Circular Técnica da Embrapa Hortaliças, 11).

MARQUES, P.A.A.; COELHO, R.D. Estudo da viabilidade econômica da irrigação da pupunheira (*Bactris Gasipaes* H.B.K.) para Ilha Solteira - SP, Brasil. **Ciência Rural**, v.33, n.2, p.291-297, mar./abr. 2003.

MARQUES, P.A.A.; FRIZZONE, J.A. Modelo computacional para determinação do risco econômico em culturas irrigadas. **Acta Scientiarum Agronomy**, v.27, n.4, p.719-727, out./dez. 2005.

van der KOOIJA, S.; ZWARTEVEENA, M.; BOESVELDA, H.; KUPERB, M. The efficiency of drip irrigation unpacked. **Agricultural Water Management**, v.123, n.12, p.103-110, may, 2013.

van GENUCHTEN, M.T. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. **Soil Science Society of America Journal**, v.44, n.5, p.892-898, sep./oct. 1980.

VILLALOBOS-REYES, S.; CASTELLANOS, J.Z.; TIJERINA-CHÁVEZ, L.; CRESPO-PICHARDO, G. Efecto de la tensión de humedad en el suelo sobre rendimiento y calidad del brócoli con riego por goteo. **Terra Latinoamericana**, v.23, n.3, p.321-328, jul./sep. 2005.