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WATER DEPLETION DEPTH FOR IRRIGATION OF POTATO CULTIVAR ÁGATA

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KEYWORDS

soil water, potato cultivars, evapotranspiration.

ABSTRACT

Potato (*Solanum tuberosum L.*) cultivation has a high demand for management and treatments during the vegetative cycle in the field. Among these requirements, water management is a limiting factor of tuber productivity and quality. This study aimed to determine the most appropriate soil water depletion depth for irrigation management in potato crops of Ágata cultivar, under the edaphoclimatic conditions of Guarapuava-PR, considering its influence on crop vegetative development. The study was conducted using four water depletion depths in the soil (12, 24, 36, and 48 mm). The different irrigation treatments promoted differences in shoot dry mass, leaf area index (LAI), number of tubers per plant, and productivity. The highest yield was observed for 27.62 mm depletion. When irrigation depth was increased to 48 mm, tubers showed individual mass reduction and hence productivity, affecting commercial classification. A cumulative depletion of about 27 mm between irrigations proved to be the most adequate management to supply the water demand of Ágata potato cultivar.

INTRODUCTION

Potato is of extreme importance as a food source for its carbohydrate richness and potential volume production worldwide (FAO, 2014). Its cultivation is generally considered high-cost (Jadoski et al., 2012), with high use of fungicides and herbicides and other inputs; however, it can present a high investment income (Darolt et al., 2004). According to Reichert et al. (2012), it is a source of direct and indirect jobs in the production and commercialization chains.

Given the need to adjust management practices to high production costs, Fernandes et al. (2010) emphasized the great importance of choosing the proper cultivar and the need for accurate information on field management. Regarding the management of cultivation conditions, Fernandes et al. (2011) and Mantovani et al. (2013) highlighted the responses of the crop to irrigation since an adequate water availability helps cultivars to express productive potential. In this sense, Marquelli et al. (1988) considered potato crops as sensitive to water stress at all developmental stages, which, according to Yuan et al. (2003), is high in this crop due to its shallow root system.

Studies performed by Ahmadi et al. (2017) showed that changes in hydric availability can lead to several disturbances such as hollow heart, malformation, enlarged lenticels, and reduced productivity. In studies conducted by Bezerra et al. (1998), productivity reductions of up to 70.5% were observed under water deficit, mainly in tuberization, reducing the size and quantity of tubers.

According to Quadros et al. (2010), the cultivar Ágata shows good productive potential and is the most produced table cultivar in Brazil currently. According to Pereira et al. (2005), in addition to high productive potential, it has good agronomic characteristics well adapted to the consumer market standards but is sensitive to certain cultivation conditions, especially water availability in the soil.

In terms of irrigation, Mantovani et al. (2014) stressed the importance of research results to support economic and effective management of irrigation in potato crops. For Pavlista (2015), the lack of knowledge about an optimal irrigation depth can economically affect potato cultivation, especially for cultivars less tolerant to water stress such as Atlantic and Ágata.

In production fields, practical difficulties, and relative lack of adequate technical knowledge on irrigation management are factors that reduce the efficiency of irrigated agriculture (Xavier et al., 2006). Therefore, barriers are often built in the production fields, serving as justification for not using such techniques in crops (Reichert et al., 2012).

In Guarapuava-PR region, where annual mean rainfall is above 1,500 mm, total precipitation depths may be erroneously interpreted as the lack of irrigation need, without considering water availability distribution

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throughout the crop cycle, as well as disregarding crop demands (Wagner et al., 2009). Cunha et al. (2014) and Admasu et al. (2016) believe that such interpretation, in many cases, prevents cultivars from achieving their productive potentials.

In this context, the need for studies on water supply management, as a tool to increase productivity and economic returns in potato cropping, becomes evident. Thus, the objective of this study was to determine the depth of soil water depletion most suitable for irrigation management of Ágata cv. potato, under the soil and climatic conditions of Guarapuava-PR, considering its influence on vegetative development and crop production.

MATERIAL AND METHODS

The study was carried out in an area of the Research Center for Potato Production and Microclimate, Department of Agronomy, Universidade Estadual do Centro Oeste - UNICENTRO (25º23'02 "S and 51º29'43" W), in the municipality of Guarapuava-PR (Brazil), from November 2013 to May 2014.

The local soil is classified as *Latossolo Bruno*, acid dystrophic (Embrapa, 2013). According to the classification of Köppen (1948), the local climate is characterized as humid mesothermal (*Cfb*), with mild summers and no well-defined dry season. Average temperatures are high between October to March (below 22°C) and low between April to September (between -3°C to 18°C). According to Wagner et al. (2009), the average annual rainfall is 1730 mm.

Table 1 shows the data on local soil chemical characteristics. Based on this, 90 days before planting, soil base saturation was adjusted to 65%, according to Jadoski et al. (2009), with the application of limestone (dolomitic, PRNT 80%) at a dosage of 1.20 t ha^{-1}. Planting fertilization consisted of 4 t ha^{-1} of the formulation 04-14-08 (NPK), applied in-furrow prior to seed tuber distribution, based on the best results for productivity considered by Fernandes & Soratto (2013).

TABLE 1. Chemical properties of the soil in the experimental area.

P Mehlich	O.M.	pH	K	Ca	Mg	H+Al	Al	SB	CEC pH 7.0	V
mg dm^{-3}	dag dm^{-3}	$CaCl_2$		....................................Cmol$_c$ dm^{-3}...						%
1.83	3.73	5.28	0.36	3.8	2.3	4.91	0.02	6.46	11.37	56.8

Planting was carried out on November 8, inside a mobile high-tunnel greenhouse on rails. It is 3.5 m high, 8 m wide, 16 m long, and covered with translucent polypropylene roof tiles. This covering structure was usually kept away from the experimental units. When it rained, it was moved, by electronic drives, to cover the plots and prevent them from being rained upon. This way, water depletion depth could be controlled between the irrigations provided for treatments.

Seed-tubers of the cultivar Agatha were used in the experiment. First-generation certified seeds (G1) were provided by Embrapa unit in Canoinhas-SC (Brazil). Planting was carried out manually in grooves by distributing type II seed tubers (40-50 mm diameter) into rows spaced 0.80 m apart and 0.25 m within the row, with a stand of 50 thousand plants ha^{-1}, according to Sales et al. (2014).

Plant emergence was considered when 50% of tuber shoots were visible above the soil surface (8 days after planting - DAP). Ridging was carried out 10 days after emergence (DAE) when plants presented, on average, two stems and about ten leaves.

Preventive fungicide spraying was carried out for control of late blight, caused by *Phytophthora infestans*, and of early blight, caused by *Alternaria solani*, which are widespread in potato growing areas, according to Töfoli et al. (2016). Insect control was performed only when absolutely necessary. We used products and dosages registered for the crop. Weed was controlled manually during the period, only when necessary as well.

Treatments were composed of four soil-water depletion depths (12, 24, 36, and 48 mm), which are based on studies developed by Aguiar Netto et al. (2000) and Grimm et al. (2011). The experimental design was completely randomized (CRD) with four replications (16 experimental units). Each experimental unit had 4.0 m² and was limited by plastic films, inserted to 50-cm depth to avoid lateral water movement between plots.

Soil moisture was monitored by a time-domain-reflectometry (TDR) equipment, considering measurements at depths from 0 to 25 cm, as recommended by Coelho et al. (2005) and Ahmadi et al. (2013).

Irrigations were applied when the soil reached the depletion limit predetermined for each treatment, raising soil-water content again to the condition of field capacity. Soil water retention curve was determined at depths from 0 to 25 cm (Equation 1).

$$Y = 0.191 + 0.0454e\text{-}x/4.15 + 0.392e\text{-}x/0.214 \quad (1)$$

In which:

Y = volumetric content of soil water (cm^3 cm^{-3}),

X = matric potential between 0.06 and 15 bar.

Irrigations were performed using a drip system, with a control head composed of one hydrometer, fast closing valves, pressure controller and filter. Dripping tubes were set in single lines, with drippers spaced 0.25 m, and total flow of 4 liters h^{-1} per linear meter. The system presented a Christiansen Uniformity Coefficient (CUC) of 93.18%, a Uniform Distribution Coefficient (CUD) of 95.48%, and the efficiency of application of 88.64%. In the first 16 days after planting, the plants of all treatments received the same amount of irrigation for suitable moisture conditions for the initial establishment of the crop.

Cultivation cycle, from planting to harvest, lasted 110 days. The climate data of the cultivation period in the field were obtained from the UNICENTRO / IAPAR Meteorological Station, located approximately 200 m from the experimental area.

During the cropping cycle, canopy morphology was evaluated by measuring the leaf area index (LAI), stem length and number, and shoot dry mass (SDM). Measures were taken at 60 days after planting (DAP) when plants were approximately at their maximum vegetative development. Except for LAI, measures were performed in 10 plants from each experimental unit, defined at random. LAI was determined in a non-destructive manner using a LICOR (LAI 2200) plant canopy analyzer, considering all vegetative canopy of plants in plots.

Stem length was determined by a graduated measuring tape (in mm), measuring only the main stems originating from emergent shoots of seed potatoes; measures were taken from ground level to the apical end of the stem. Stems and leaves collected for SDM determinations were dried in a forced circulation oven at 65 ºC until reaching a constant mass. At 109 DAE, the crop was desiccated aiming to standardize tuber aerial part and outer peel for harvesting. An herbicide with paraquat as an active ingredient (200 g L^{-1}) was used at a dose of 2 L ha^{-1}, according to the manufacturer's recommendations, sprayed at an application rate of 120 L ha^{-1}.

Productivity was determined in plants taken from the useful area of each plot. The number of tubers was counted per plant in each treatment. The yield was measured by weighing tubers from harvested plants. Productivity results were extrapolated to a plantation stand of 50,000 ha^{-1} plants.

The commercial classification of potato tubers was based on the Administrative Rule no. 69 of February 21, 1995, of the Ministério da Agricultura, Pecuária e Abastecimento (MAPA, 1995), considering the cross-sectional diameter of each tuber determined by a pachymeter.

Statistical analysis was performed using the Statistical Analysis System (SAS® 9.2) software. Data were submitted to analysis of variance and regression at a significance level of 95%. All the data were verified for normality of residuals by the Shapiro-Wilk test and for homogeneity of variances by the Bartlett test, at 95% probability. Pearson’s analysis was performed to compare vegetative canopy components and tuber yield.

RESULTS AND DISCUSSION

During the experimental period, the average daily temperature varied between 16.6 and 26.1 ºC, and relative humidity (RH) between 94.7% (at 14 DAP) and 50% (at 90 DAP); overall mean during growth period was 21 °C and 74% RH. During cultivation cycle, mean photoperiod at latitude -25.1º was 12.85 hours, but local sunshine hours had a mean value of 6.9 hours of daily sun, which is below local historical average and higher than the 7.5 hours for spring-summer , but within the annual average range between 6.5 and 7.0 hours of sunshine, as presented by Wagner et al. (2009). Figure 1 shows the variations of some climatic elements throughout the crop cycle, as well as results referring to the irrigation depth applied in the different treatments.

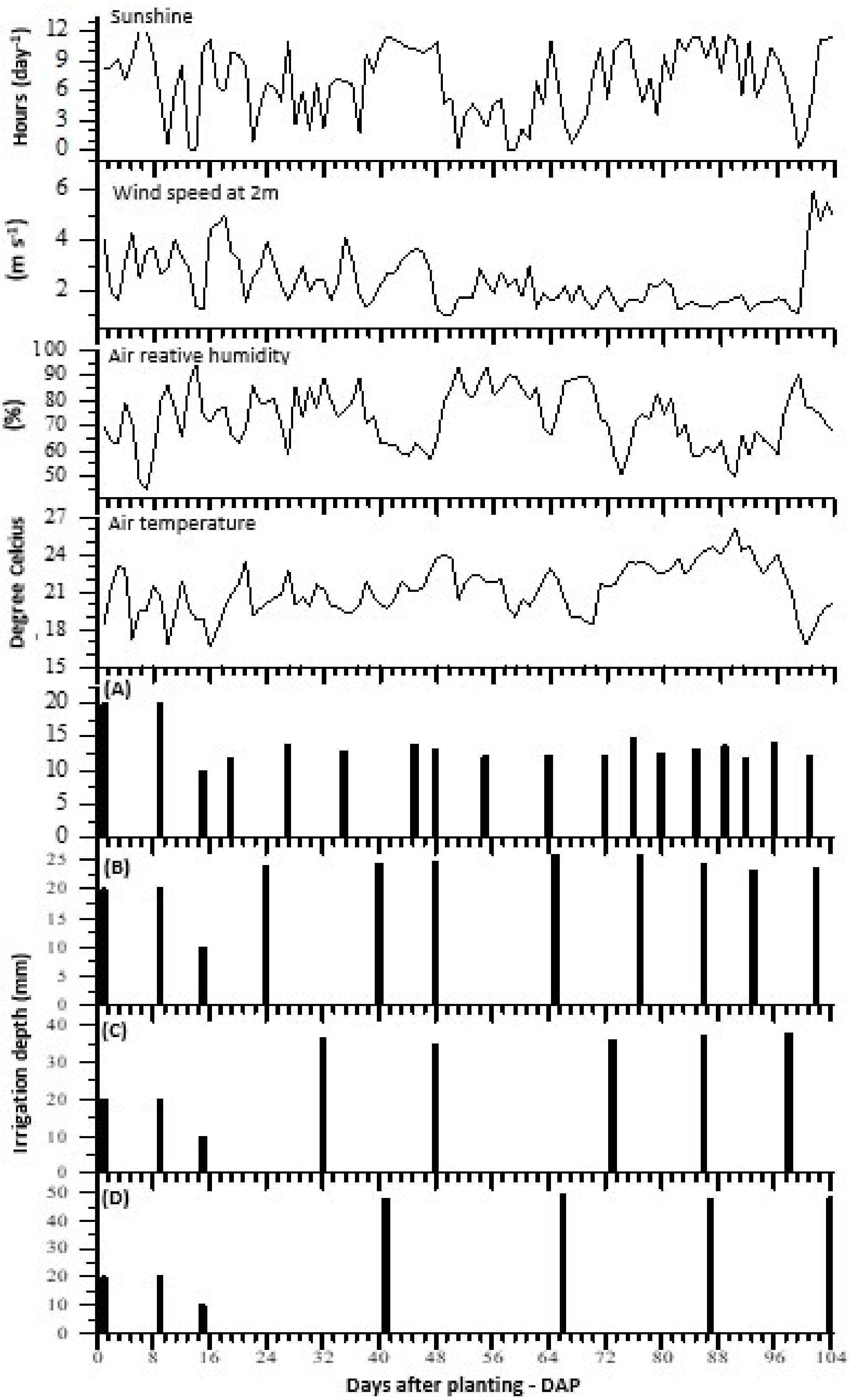

FIGURE 1. Average daily values of climatic conditions: sunshine, wind speed, relative air humidity, and mean air temperature in the experimental area, and irrigation depth applied to each treatment for soil water depletion of 12 mm (A), 24 mm (B), 36 mm (C) and 48 mm (D) during the cycle of potato cv. Ágata.

Based on soil water depletion, 15 irrigations were applied for T1 treatment (12 mm), 8 irrigations for T2 (24 mm), 5 irrigations for T3 (36 mm), and 4 irrigations for T4 (48 mm). The last irrigation was performed for T3 at 91 DAP, for T1 and T4 at 93 DAP and for T2 at 98 DAP (Figure 1).

The total irrigation depths were 244.6 mm, 246 mm, 232.8 mm, and 243.3 mm for T1, T2, T3, and T4 respectively (Figure 1), including the 50 mm applied in the three uniform irrigations during initial crop establishment. Average wind speed decreased during the growing cycle but always above 2m s^{-1}, which favored crop evapotranspiration. Irrigations were more concentrated between from 72 to 104 DAP when higher temperatures and lower RH indices were registered.

During vegetative development, the average number of stems was of 2.88 stems $plant^{-1}$ and the length of the largest stem of 57.03 cm, and the effect of depletion depths was not significantly different. These results agree with those verified by Marquelli et al. (1988) and by Wurr et al. (2001), who did not observe the effect of different irrigation depth on the number and length of stems produced in potato crop using the cultivars Achat and Estima, respectively.

Mantovani et al. (2014) also pointed out that stems stop growing after tuber formation (35 DAE) since they become main drains competing for photoassimilates produced by the plant, explaining partly stem reduction and production of new stems. Results related to the influence of available water on stem growth are also presented and discussed by different authors such as Yuan et al. (2003), Tekalign & Hammes (2005), and Fernandes et al. (2010). For Feltran & Lemos (2005), the number of stems is a parameter more related to seed-tuber characteristics than to management conditions, including water availability.

Shoot dry matter accumulation (SDM) was significantly influenced by depletion depths. Regression analysis showed significance for quadratic equation (Figure 2) with a maximum point at 20.67 mm depletion, in which dry matter was 33.45 g $plant^{-1}$. Equation showed that larger depletion depths caused greater reductions in shoot biomass. Similar results were observed in a study by Yuan et al. (2003), in which dry biomass decreased as depletion depth increased.

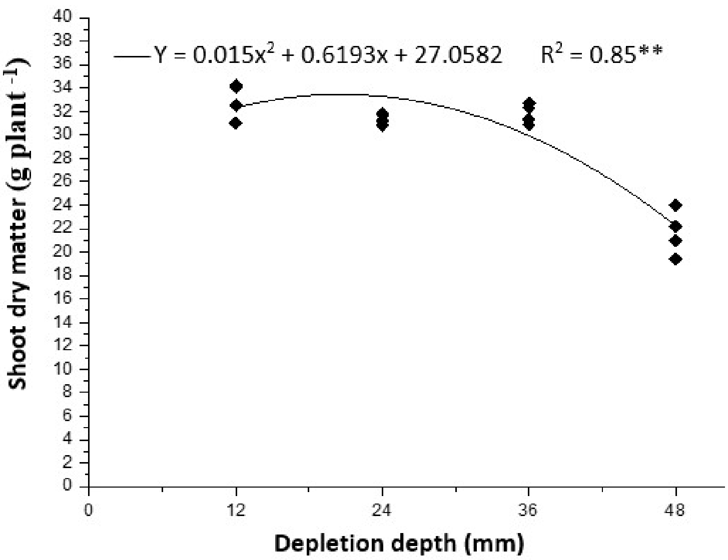

FIGURE 2. Shoot dry matter of potato plants cv. Ágata at 60 days after emergence submitted to four soil-water depletion depths. ** Significant at 1% (P<0.01)

The increase in soil water depletion has led to a marked decrease in SDM accumulation. Lower irrigation frequencies led to a decreased in vegetative development, leading to reductions in dry matter accumulation. This result agrees with that found by Aguiar Netto et al. (2000), who determined that greater soil drying between consecutive irrigations reduces physiological indices of potato growth.

Dry soils may generate losses by lowering plant turgor pressure, and consequently reducing shoot cellular expansion and growth, plants also tend to decrease the production of new leaves (Wang et al., 2011; Barnaby et al., 2015). In addition, there is an interference with photosynthesis and reduction of normal metabolic processes in plants, which generates stress and interfere significantly with vegetative development (Bezerra et al., 1998, Aguiar Netto et al., 2000).

In very humid soils, the availability of oxygen in roots decreases, impairing absorption and interfering with normal plant metabolism (Ahmadi et al., 2013), reducing SDM and productivity (Aguiar Netto et al., 2000). In this sense, cultivation in places with high precipitation rates such as the case of Guarapuava, where annual precipitation is generally above 1700 mm (Wagner et al., 2009), requires that producers have more information about crop management and irrigation systems in order to avoid excess or deficit of water supplementation, as long as crop losses may occur due to both deficit (Barnaby et al. (2015) and excess water in the soil (Ahmadi et al. (2017).

Water depletion management significantly influenced the LAI of potatoes cv. Ágata. A statistical significance was observed in a quadratic regression model with a maximum point at 3.63 for a depletion depth of 18.67mm (Figure 3).

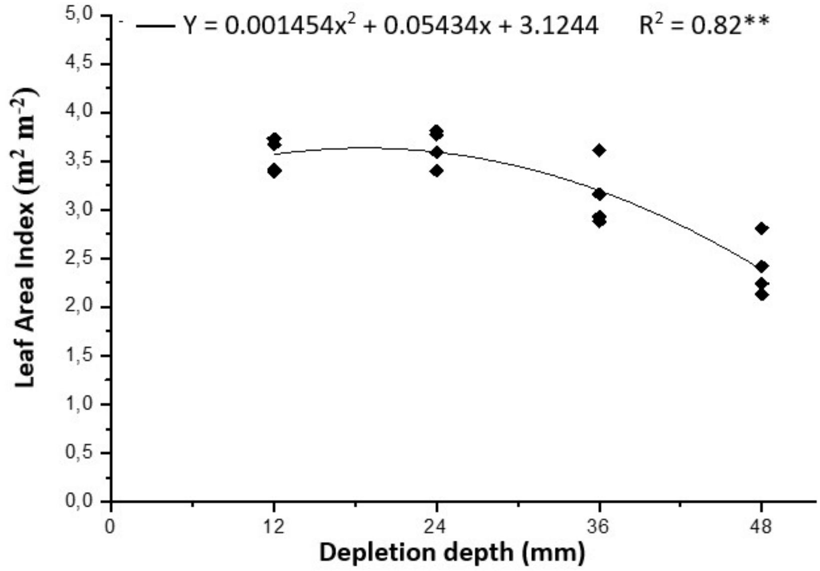

FIGURE 3. Leaf area index of potato plants cv. Ágata submitted to four soil-water depletion depths.
** Significant at 1% ($P<0.01$)

In this study, the mean IAF was close to that observed by Aguiar Netto et al. (2000) who verified an IAF of 3.50 for cultivar Aracy and also agrees with Wang et al. (2011) who demonstrated that LAI is rapidly affected by water deficiency. Kar & Kumar (2007), studying potato cultivation, observed a positive effect of soil water availability on LAI and SDM of plants, demonstrating the importance of establishing crop responses to available water in the soil.

IAF evidenced the same trends as those of SDM. Pearson's analysis showed a correlation of 78% for LAI and 73.8% for SDM compared to applied treatments. These results were also observed by Silva et al. (2007), who highlighted direct effects of soil moisture on the development of crop vegetative components, reducing LAI and shoot growth under conditions of available water reduction. It is also noted that the depths from 24 mm also obtained a lower LAI, like that demonstrated by SDM.

During the period of water deficiency, the efficiency of water use is altered, impairing vegetative development of potato plants (Liu et al., 2005), draining nutrients for accumulation in production organs (Wang et al., 2011), reducing cell expansion, decreasing tissue growth, and consequently dry matter and LAI (Barnaby et al., 2015).

The following variables: mean number of tubers per plant, mean tuber weight, and yield were influenced by depletion depths, for which statistical significance was observed in a quadratic regression model (Figures 4, 5 and 6). With this model, we observed that the average number of tubers per plant presented a behavior with a minimum point of 5.90 tuber $plant^{-1}$ for a 26.53 mm depletion depth (Figure 4).

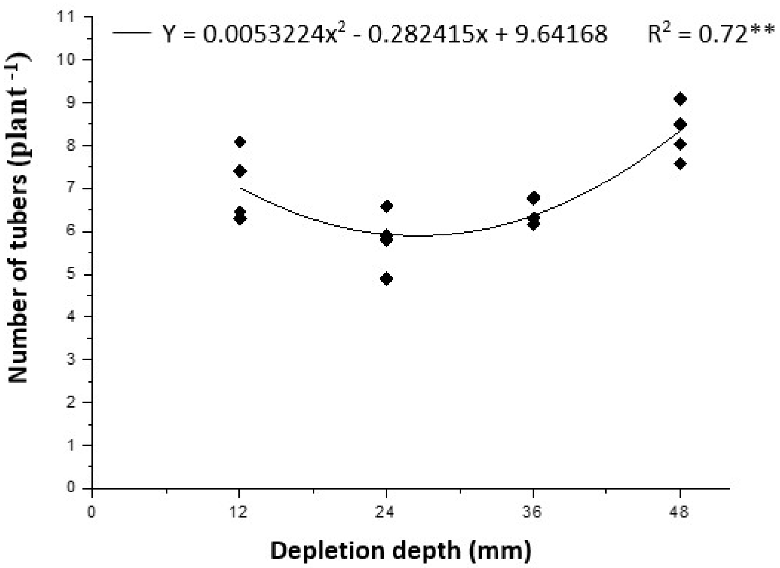

FIGURE 4. Number of tubers of potato plants cv. Ágata submitted to four soil-water depletion depths.
** Significant at 1% ($P<0.01$)

The adjusted regression for mean tuber weight (Figure 5) showed a maximum of 116.16 g tuber^{-1} at a depletion depth of 27.41 mm. This result shows that the average tuber weight increase is directly related to the lower number of tubers, since only 6 tubers per plant were harvested in this range (Figure 4). This number increases in the other ranges reaching 7.3 and 8.6 for accumulated depletion depths of 12 and 48 mm, respectively.

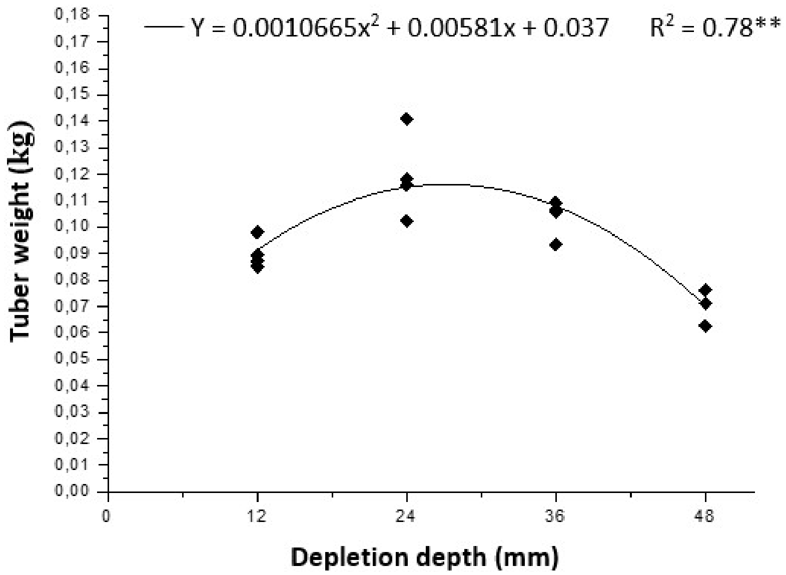

FIGURE 5. Average weight of tubers of potato plants cv. Ágata submitted to four soil-water depletion depths.
** Significant at 1% (P<0.01)

A depletion depth of 27.62 mm reached a maximum yield of 32.981 kg tuber ha^{-1} (Figure 6). The reverse behavior of the number of tubers per plant (Figure 4) and tuber mean weight (Figure 5) indicates that for cultivar Ágata, the optimum irrigation depletion depth is approximately 27.5 mm. Within this management depth, productivity will be composed of a smaller number of bigger tubers per plant, which, according to Yuan et al. (2003), are positive characteristics for acceptance and valuation within the commercial classification for potato consumption.

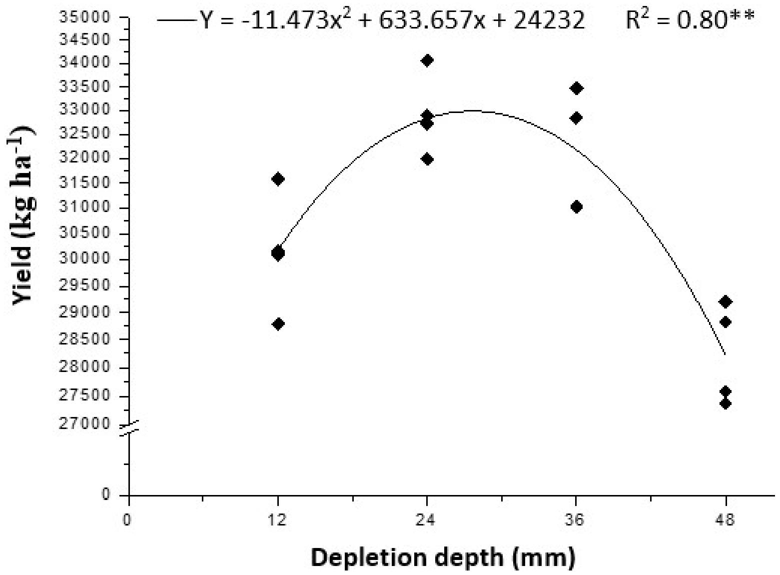

FIGURE 6 Yield of potato plants cv. Ágata submitted to four soil-water depletion depths. ** Significant at 1% (P<0.01).

The largest number of tubers was observed at a depletion depth of 48 mm, being of 8.35 tuber plant^{-1} (Figure 4). However, the same depletion depth promoted smaller tubers, with a mean weight of 70.20 g tuber^{-1} (Figure 5) and the lowest productivity among all treatments, being of 28,215 kg tuber ha^{-1} (Figure 6).

Pearson's analysis showed a correlation of 65% between productivity and LAI and of 62% between productivity and SDM. This demonstrates that tuber productivity is strongly related to the development of vegetative canopy. This can be based on LAI and SDM presented by the crop at 60 DAP when plants reached their maximum vegetative development.

If there is no LAI expansion due to water stress, carbon and energy productions are reduced, causing the plants to direct their metabolism to escape measures, that is, a defense mechanism that distributes assimilates to the underground organs (Suassuna et al., 2012). This impairs plant development and has negative consequences on tuber production, as indicated by the results presented in this study.

Water stress affects productivity and accumulation of photoassimilates in tubers, which may have an increased number of tubers but in smaller sizes, as already observed by Pulz et al. (2008). These authors verified that, under irrigation, there was a larger number of tubers of smaller size, which are classified as non-tradable. Smaller depletion depths with very frequent irrigation tend to reduce air space in the soil, adversely affecting root development and tuberization, as verified by Ahmadi et al. (2017).

Some studies on soil-water management have shown effects on crop productivity. Onder et al. (2005) observed that water deficiency reduced the development of production components and hence productivity. Similarly, Ahmadi et al. (2013) verified that the dynamic water movement in the soil profile, with wetting and drying cycles, is a positive factor for root growth and tuber expansion. These authors asserted that severe water deficits, comparable to a 48-mm depletion depth, reduce yields by up to 56% when compared to the best management, which replaces 25% of the storage capacity of the soil, based on crop evapotranspiration.

Table 2 displays the results obtained for the commercial classification of tubers, considering transversal diameters.

TABLE 2. Tuber size classification for potato plants of cultivar Ágata submitted to four soil-water depletion depths.

Depth (mm)	Classification (%)			
	I (>85 mm)	II (45-85 mm) *	III (33-45 mm) *	IV (<33 mm) *
12	0.0	48.638 BC	14.467 AB	36.895 A
24	0.0	69.294 AB	12.122 B	18.584 B
36	0.0	71.091 A	10.926 B	17.643 B
48	0.0	37.719 C	29.114 A	33.17 AB

* Means followed by the same letter in the column do not differ statistically from each other by the Tukey's test P <0.05.

In general, the highest percentages of tubers were found in class II, and total absence of tubers in class I. Regarding tuber classification, the cultivar Ágata does not produce large tubers of class I (Yang et al., 2015), with diameters above 85 mm, this cultivar produces predominantly tubers class II (Jadoski et al., 2012).

While class III tubers still have some market value, class IV tubers have little or no market value. Therefore, the productivity potential of this potato cultivar could have been increased if tubers of that class had improved development.

With respect to depletion depth, Table 2 shows that depths of 24 to 36 mm resulted in a higher proportion of class II tubers and consequently lower of classes III and IV. At a depth of 12 mm, there were no significant statistical differences for classes II and III. Conversely, the depth of 48 mm showed the lowest quantitative potential for class II tubers and showed higher amounts of smaller tubers of classes III and IV.

When compared to total productivity, tuber commercial classification followed the plot of yield curves (Figure 6), concentrating more tubers on class II, with a higher commercial value for the depths of 24 and 36 mm. Along with the others, these results contribute to consolidating the definition of a soil-water depletion depth for irrigation management of Ágata cultivar in approximately 27 mm. The results obtained were consistent with those obtained by Ahmadi et al. (2017), Admasu et al (2016), Mantovani et al. (2014), and Onder et al. (2005), who demonstrated that potato crop is sensitive to water availability in soil, reducing tuber yield and commercial viability when under conditions of water excess or deficiency.

CONCLUSIONS

The results enable us to conclude that, under the conditions of the present study, the optimum depth of soil water depletion for irrigation management of potato cultivar Ágata is approximately 27 mm. With this depth, productivity results are maximized, with tubers of larger sizes of the commercial class II (45 to 80 mm in diameter).

The maximum development of vegetative canopy, expressed by leaf area index and total shoot dry matter production, occurs with a depletion depth of approximately 20 mm.

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REFERENCES

Admasu W, Tadesse K, Hordofa T, Deresse Y, Habte D (2016) Determining of Optimal Irrigation Regimes and NP Fertilizer Rate for Potato (*Solanum tuberosum* L.) at Kulumsa, Arsi Zone, Ethiopia. Academia Journal of Agricultural Research (4)6:326-332. DOI: http://dx.doi.org/10.15413/ajar.2016.0155

Aguiar Netto AO, Rodrigues JD, Pinho SZ (2000) Análise de crescimento na cultura da batata submetida a diferentes lâminas de irrigação. Pesquisa Agropecuária Brasileira 35(5):901-907. DOI: http://dx.doi.org/10.1590/S0100-204X2000000500006

Ahmadi SH, Agharezaee CM, Kamgar-Haghighi AA, Sepaskhah AR (2017) Compatibility of root growth and tuber production of potato cultivars with dynamic and static water saving irrigation managements. Soil Use and Management 33:106-119. DOI: https://doi.org/10.1111/sum.12317

Ahmadi SH, Agharezaee M, Kamgar-Haghighi AA, Sepaskhah AR (2013) Effects of dynamic and static deficit and partial root zone drying irrigation strategies on yield, tuber sizes distribution, and water productivity of two field grown potato cultivars. Agricultural Water Management 134:126-136. DOI: https://doi.org/10.1016/j.agwat.2013.11.015

Barnaby JY, Fleisher D, Reddy V, Sicher R (2015) Combined effects of CO_2 enrichment, diurnal light levels and water stress on foliar metabolites of potato plants grown in naturally sunlit controlled environment chambers. Physiologia Plantarum 153(2):243-52. DOI: https://doi.org/10.1111/ppl.12238.

Bezerra FML, Angelocci LR, Minami K (1998) Relações Água-Solo-Planta-Atmosfera: deficiência hídrica em vários estádios de desenvolvimento da batata. Revista Brasileira de Engenharia Agrícola e Ambiental 2(2):119-123.

Coelho EF, Vellame LM, Coelho Filho MA (2005) Sonda de TDR para estimativa da umidade e condutividade elétrica do solo, com uso de multiplexadores. Engenharia Agrícola e Ambiental 9(4):475-480. http://dx.doi.org/10.1590/S1415-43662005000400006

Cunha FF, Godoy AR, Muchalak SM, Lima SF, Leal AJF, Baio FHR (2014) Produção de cultivares de batata em diferentes sistemas de irrigação. Bioscience Journal 30(1):55-64.

Darolt M, Rodrigues A, Nazareno N, Brisolla A, Rüppel O (2004) Análise comparativa entre o sistema orgânico e convencional de batata comum. IAPAR/Paraná p1-15 Available: http://www.iapar.br/arquivos/File/zip_pdf/Darolt%20-%20BatataOrganica%20FINAL.pdf. Accessed: Ago 28, 2015.

Embrapa - Empresa Brasileira de Pesquisa Agropecuária (2013) Sistema brasileiro de classificação de solos. Embrapa, 3ed.

FAO - Food and Agriculture Organization of the United Nations (2014) International Year of The Potato – The tuber. Available: http://www.fao.org/potato-2008/en/potato/tuber.html. Accessed: Jun 18, 2015.

Feltran JC, Lemos LB (2005) Características agronômicas e distúrbios fisiológicos em cultivares de batata. Científica 33(1):106-113. DOI: http://dx.doi.org/10.15361/1984-5529.2005v33n1p106-113

Fernandes AM, Soratto RP (2013) Eficiência de utilização de nutrientes por cultivares de batata. Bioscience Journal 29(1):91-100.

Fernandes AM, Soratto RP, Evangelista RM, Silva BL, Schlick GDS (2011) Produtividade e esverdeamento pós-colheita de tubérculos de cultivares de batata produzidos na safra de inverno. Ciência Agronômica 42(2):502-508.

Fernandes AM, Soratto RP, Silva BL, Souza-Schlick GD (2010) Crescimento, acúmulo e distribuição de matéria seca em cultivares de batata na safra de inverno. Pesquisa Agropecuária brasileira 45(8):826-835. DOI: http://dx.doi.org/10.1590/S0100-204X2010000800008

Grimm EL, Heidwein AB, Radons SZ, Imaldaner IC, Trentin G, Bosco LC (2011) Produtividade da batata em função da irrigação e do controle químico da requeima. Engenharia Agrícola e Ambiental 15(2):125-130. DOI: http://dx.doi.org/10.1590/S1415-43662011000200003

Jadoski SO, Saito LR, Maggi MF, Wagner M, Reffatti TN (2012) Formas de mecanização e manejo do solo para a cultura da batata I – características da produção. Engenharia Agricola 32(5):889-899. DOI: http://dx.doi.org/10.1590/S0100-69162012000500008

Jadoski SO, Maggi MF, Kawakami J, Zandonai JG, Vieira DJ (2009) Produtividade e sanidade dos tubérculos de batata (*Solanum tuberosum* L.) sob diferentes níveis de saturação de bases e cálcio no solo. Pesquisa Aplicada & Agrotecnologia 2(2):173-187.

Kar G, Kumar A (2007) Effects of irrigation and straw mulch on water use and tuber yield of potato in eastern India. Agricultural Water Management 94(1-3):109-116. DOI: https://doi.org/10.1016/j.agwat.2007.08.004

Köppen W (1948) Climatologia: com um estúdio de los climas de la tierra. Mexico, Fondo de Cultura Economica, 104 p.

Liu F, Jensen CR, Shahanzari A, Andersen MN, Jacobsen SE (2005) ABA regulated stomatal control and photosynthetic water use efficiency of potato (*Solanum tuberosum* L.) during progressive soil drying. Plant Science 168(3)831-836. DOI: https://doi.org/10.1016/j.plantsci.2004.10.016

Mantovani EC, Delazari FT, Dias LE, Assis IR, Vieira GHS, Landim FM (2013) Eficiência no uso da água de duas cultivares de batata-doce em resposta a diferentes lâminas de irrigação. Horticultura Brasileira 31(4):602-606. http://dx.doi.org/10.1590/S0102-05362013000400015

Mantovani EC, Souza DO, Zambolim L, Sediyama G, Palaretti L (2014) Produtividade da batata irrigada por gotejamento no sul do estado de Minas Gerais. Horticultura Brasileira 32:63-68. DOI: http://dx.doi.org/10.1590/S0102-05362014000100010

MAPA - Ministério da Agricultura Pecuária e Abastecimento (1995) Portaria nº 69, de 21 de Fevereiro de 1995. p.1-7. Available: http://www.codapar.pr.gov.br/arquivos/File/pdf/batata069_95.pdf. Accessed: Jul 26, 2013.

Marquelli WA, Silva WLC, Oliveira CAS, Silva HR (1988) Resposta da cultura da batata a diferentes regimes de irrigação. Revista Latinoamericana de la Papa 1:25-34.

Onder S, Caliskan ME, Onder D, Caliskan S (2005) Different irrigation methods and water stress effects on potato yield and yield components. Agricultural Water Management 73(1):73-86. DOI: https://doi.org/10.1016/j.agwat.2004.09.023

Pavlista AD (2015) Scheduling Reduced Irrigation on 'Atlantic' Potato for Minimal Effect. American Journal of Potato Research 92(6):673-683. DOI: https://doi.org/10.1007/s12230-015-9483-3

Pereira AS, Daniels,J, Freire CJS, Bertoncini O, Nazareno NRX, Brisolla AD, Salles LAB (2005) Produção de batata no Rio Grande do Sul. Embrapa Clima Temperado, 14p. (Circular Técnica, 48)

Pulz AL, Crusciol CAC, Lemos LB, Soratto RP (2008) Influência de silicato e calcário na nutrição, produtividade e qualidade de batata sob deficiência hídrica. Revista Brasileira de Ciência do Solo 32(4):1651-1659. DOI: http://dx.doi.org/10.1590/S0100-06832008000400030

Quadros DAD, Lung MC, Ferreira SMR, Freitas RJSD (2010) Qualidade de batata para fritura, em função dos níveis de açúcares redutores e não-redutores, durante o armazenamento à temperatura ambiente. Acta Scientiarum Technology 32(4):439-443. DOI: http://dx.doi.org/10.4025/actascitechnol.v32i4.6663

Reichert LJ, Padilla MC, Gomes MC, Cáceres RS (2012) Análise socioeconômica da produção de batata nos municípios de Sanlúcas de Barrameda/Espanha e São Lourenço do Sul/Brasil. Revista de Ciências Agrárias 35(1):143-156.

Sales LLSR, Jadoski,SO, Saito LR, Ramos MSD, Pott CA (2014) Desenvolvimento vegetativo da cultura da batata em função da amontoa e espaçamento de plantas. Revista Caatinga 27(1):83-92.

Silva JÁ, Pires RCM, Sakai E, Silva TJA, Andrade JE, Arruda FB, Calheiros RO (2007) Desenvolvimento e produtividade da cultura da batata irrigada por gotejamento em dois sistemas de cultivo. Engenharia Agrícola 27(2):354-362. DOI: http://dx.doi.org/10.1590/S0100-69162007000300004

Suassuna JF, Nascimento R, Oliveira ACM, Brito KSA, Melo AS (2012) Produção de fitomassa em genótipos de citros submetidos a estress hídrico na formação do porta-enxerto. Revista Brasileira de Engenharia Agrícola e Ambiental 16(12):1305-1313. DOI: http://dx.doi.org/10.1590/S1415-43662012001200007

Tekalign T, Hammes PS (2005) Growth and productivity of potato as influenced by cultivar and reproductive growth. Scientia Horticulturae 105(1):29-44. DOI: https://doi.org/10.1016/j.scienta.2005.01.021

Töfoli JG, Melo PCT, Domingues RJ, Ferrari JT (2016) Controle da requeima e pinta preta da batata por fungicidas e seu reflexo sobre a produtividade e a qualidade de tubérculos. Arquivos do Instituto Biologico 83(1)1-12. DOI: http://dx.doi.org/10.1590/1808-1657001172013

Wagner MW, Jadoski SO, Saito LR, Suchoronczek A, Scabeni CJ (2009) Comportamento de características climáticas para o manejo de culturas agrícolas em Guarapuava, centro-sul do estado do Paraná. Pesquisa Aplicada & Agrotecnologia 2(3):41-49.

Wang FX, Wu XX, Shock CC, Chu LY, Gu XX, Xue X (2011) Effects of drip irrigation regimes on potato tuber yield and quality under plastic mulch in arid Northwestern China. Field Crops Research 122(1):78-84. DOI: http://dx.doi.org/10.1016/j.fcr.2011.02.009

Wurr DCE, Fellows J.R, Akehurst JM, Hambidge AJ, Lynn JR (2001) The effect of cultural and environmental factors on potato seed tuber morphology and subsequent sprout and stem development. The Journal of Agricultural Science 136(1):55-63.

Xavier LF, Costa RDF, Costa EDF (2006) Adoção de tecnologias poupadoras de água na fruticultura irrigada do Vale do São Francisco: uma comparação entre percepções de colonos e empresas. Economia e Sociologia Rural 44(2):219-241. DOI: http://dx.doi.org/10.1590/S0103-20032006000200004

Yang Y, Achaerandio I, Pujolà M (2015) Classification of potato cultivars to establish their processing aptitude. Journal of the science of food and agriculture - *on line*. Available: https://onlinelibrary.wiley.com/doi/abs/10.1002/jsfa.7104. Accessed: Oct 16, 2017.

Yuan BZ, Nishiyama S, Kang Y (2003) Effects of different irrigation regimes on the growth and yield of drip-irrigated potato. Agricultural Water Management 63(3):153-167.