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Cientific Paper

Management of ridging and plant spacing on yield and characteristics of potato tubers

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Abstract

The plant spacing and ridging are essential practices for the cultivation of the potato. The study was conducted in the experimental area of Department of Agronomy, Universidade Estadual do Centro Oeste – Unicentro, Guarapuava - PR. The objective was to evaluate the effects of different plant spacing in the row crop and time of ridging on the yield and characteristics of potato tubers. The experiment was structured in a randomized block designin - factorial 4 x 4 with four replications, consisting of four managements / times of ridging, being one witness without ridging and four plants spacing in the row from 16 to 34 cm that resulted in plant populations ranging from 36,765 to 78,125 plants ha^{-1}, respectively. Characteristics such as average weight, size, productivity and greening of tubers were evaluated. It was found that the greater spacing between plants linked to the achievement of ridging at planting stressed as the best management alternative for the production of potatoes for consumption.

Key words: potato production; plant management; equipment for ridging

Manejo da amontoa e espaçamento de plantas na produtividade e caracteristicas dos tubérculos de batata

Resumo

O espaçamento de plantas e a amontoa são práticas essenciais para o cultivo da batata. O estudo foi conduzido em área experimental do Departamento de Agronomia, na Universidade Estadual do Centro Oeste – Unicentro, em Guarapuava – PR. O objetivo foi avaliar os efeitos de diferentes espaçamentos de plantas na linha de cultivo e épocas de realização da amontoa sobre a produtividade e características dos tubérculos de batata. O experimento foi estruturado em delineamento blocos ao acaso em fatorial 4 x 4 com quatro repetições, composto por quatro manejos/épocas de realização da amontoa, sendo um deles testemunha sem amontoa e, quatro espaçamentos de plantas na linha, entre 16 e 34 cm, que resultaram em população de plantas que variou de 36.765 a 78.125 plantas ha^{-1}, respectivamente. Foram avaliadas características como massa média, tamanho, produtividade e esverdeamento dos tubérculos. Verificou-se o cultivo com maior espaçamento entre plantas associado à realização de amontoa no momento do plantio destacou-se como sendo a melhor alternativa de manejo para a produção de batata para o consumo.

Palavras chave: bataticultura; manejo de plantas; equipamento para amontoa

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Manejo del aporcado y espaciamiento de plantas en la productividad y características de los tubérculos de patata

Resumen

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Palavras chave: bataticultura; manejo de plantas; equipamento para amontoa

Introduction

The crop of potatoes (*Solanum tuberosum* L.) are highly relevant in the scenario of Brazilian agriculture, yet still historically it has been observed great variation in levels of productivity and quality of the production obtained (BISOGNIN et al. 2008, SONNENBERG 1975). For this it is necessary to generate information for better subsidizing technical decisions taken, particularly with regard to crop management. In this particular HENRIKSEN et al. (2007) point out that the ridging and spacing between plants exert great influence on the formation and tuber yield. These parameters of management also demonstrated to be very important for the components of production of other tuberous, as verified GOMES et al. (2010).

JADOSKI et al. (2012) emphasize that the volume and quality of production of potato tubers essentially depend on management practices, being that extended to by appropriate practices who aim to provide certain favorable conditions for plant development, production or offsetting environmental shortcomings, among these managements stands out soil disturbance with ridging. To SILVA et al. (2007) the soil management may favor the crop and harvesting process by improving tuber yield, and point out that the character income is more strongly associated with the production components such as size, number and average weight of tubers produced.

To AHMADVAND et al. (2009) the definition of the best spacing between seed tubers should take into consideration if the purpose of production is for potato consumption or seed potatoes, because the results of cultivation in different plant spacing are usually associated with different sizes of tubers at harvest. CALISKAN et al. (2009) observed that the potato crop tends to maintain a ratio of reducing the size and increasing the number of units of tubers produced with the increase of density of plants.

As BRUNE e MELO (2001) the assessments of post-harvest are important because they can insert more elements in relation to the definition of the best strategy for cultivation. The classification of potato tubers is performed with product separation in homogenous class, unifying language of the market and the entire production chain. FERNANDES et al. (2011) highlight the growing importance of the need for classification of tubers for marketing purposes, since it is increasing the valuation of the appearance of tubers, which in this case involves different characteristics that can highlight the integrity of skin, size, color and shape of tubers.

Still on the characteristics of post-harvest NEMA et al. (2008) emphasize that exposure of potato tubers to light triggers a process of tuber greening which occurs due to chlorophyll synthesis with the transformation of chloroplasts in amyloplasts, associated with the accumulation of glycoalkaloids which change the taste of tubers reducing the possibility of commercialization. As BRUNE e MELO (2001) this process is undesirable, however, variable

from genotype to genotype. These authors found that the Delta and Monalisa cultivars showed tubers with medium tuber greening trend, now the cultivar Agate, showed strong tuber greening.

In this context, this experiment was to evaluate the effects of different plant spacing in the line of cultivation and periods of realization of ridging in under the characteristics and productivity of potato tubers in order to define the best combination of these factors for crop management in the field.

Material and Methods

The experiment was conducted in the experimental area of the Department of Agronomy, of the Universidade Estadual do Centro Oeste – Unicentro, in Guarapuava – PR, 25°23'02" S, 51° 29'43" W. The regional climate is classified as Cfb - mesothermal humid subtropical.

The local soil is classified as Latossolo Bruno Distroférrico1, according to methodology of EMBRAPA (2006). After three years of fallow the experimental area was cultivated with wheat prior to potato cultivation. Approximately 90 days before the onset of the experiment were collected soil samples from the layer of 0 to 0.20 m for chemical analysis (Table 1), based on their results was performed liming to 60 days before planting in order to raise the pH of soil to 6.2, as recommended by PULZ et al. (2008), with lime incorporation until approximate depth of 0.30 m.

Soil density was evaluated 15 days before soil preparation for planting showed initial values of 1.27 and 1.29 g cm^{-3} for the depths of 10 and 30 cm in the soil, respectively.

The experiment was structured in a randomized block design in 4 x 4 factorial with six replications, comprising four periods of realization of ridging (Factor A) and four plants in row spacing (Factor B), as described in Table 2, where also presents the resulting plant population considering the fixed spacing between rows of 0.80 m. Each plot consisted of four rows of 6.0 m long, considering as useful area of 4.0 m each of the two central rows from the each plot.

The plant arrangement usually practiced by farmers in the region is 25 cm in row and 80 cm between rows, with stand in the planting of approximately 50 000 ha^{-1} tubers.

The land was prepared for planting with the following sequence of operations with implements: a) disc harrow, b) rotary hoe, c) leveling harrow, d) scarifier, e) ridger for opening of planting furrows.

The fertilizer was applied in the furrow at planting date preceding the distribution of seed tubers, with 3.3 t ha^{-1} of NPK 4-14-8. The planting was carried out on December 23th 2011, using the cultivar Ágata with certified seed of the first generation (G1) and tubers of the type 2 (diameter between 40 to 50mm).

The treatments under of the ridging were 1) ridging on December 23th 2011 (ridging at planting or early), 2) ridging on January 19th 2012 at 10 days after emergence (DAE), which is the most widespread practice among producers in the region, 3) ridging on January 29th at 20 DAE, and 4) Without performing ridging. We used a rotary hoe disc suitable for this purpose.

The desiccation of plants in order to standardize the characteristics of tubers for harvest was performed at 85 DAE with herbicide application (IA) Paraquat. The harvest took place on April 20th, 2012 at 100 DAE. This operation was performed manually in the useful area of the plots and with a mechanized starter on the edges remaining.

The traits analyzed were: a) productivity, obtained by weighing of tubers produced by ten plants randomly chosen from the floor area of each plot, which were washed and weighed immediately after harvest. The results were converted to kg ha^{-1} taking into account the stand of plants in each treatment. These tubers were used afterwards for other evaluations, being b) the average tuber weight, considering the total weight of the tubers and number of harvested tubers, c) number of tubers per plant, based on the relation between the total number of

Table 1. Soil chemical characteristics of the experimental area.

P Mehlich mg dm^3	M.O mg dm^3	pH C_aCl_2	K cmol dm^{-3}	Ca cmol dm^{-3}	Mg cmol dm^{-3}	H+Al	Al	SB	CTC	V%	Micronutrients (mg dm^{-3})		
											Cu	Mn	Zn
1.84	41.1	5.1	0.36	3.7	2.1	4.89	0.02	6.38	11.28	56.2	1.3	41.4	0.9

Table 2. Treatments and resultant plant population with fixed spacing of 0.80 m between rows.

Factor A Periods of Ridging	Factor B Plant spacing in the row	Population in planting (plants ha^{-1})
Ridging in planting	16 cm	78.125
Ridging in the 10 DAE	22 cm	56.818
Ridging in the 20 DAE	28 cm	44.643
Control (without ridging)	34 cm	36.765

DAE: Days after emergence

tubers and harvested plants d) classification of tubers by size.

For classification by size the diameter was measured using a digital caliper. The classification was carried out considering the commercial classes: 1) ≥ 85 mm 2) 45.1 to 84.9 mm, 3) from 33 to 45 mm and 4) <33mm, according to the decree No. 69, 1995 of the Ministry of Agriculture, Livestock and Supply – MAPA/Brazil.

It was evaluated the occurrence rate of tuber greening, based on the adaptation of the scale proposed by BRUNE e MELO (2001). It was considered the occurrence and intensity of tuber greening, the latter being carried out by assigning values to percentages according to greenish area of each tuber: 1% to 30% (weak tuber greening), % (Medium tuber greening), 70% (strong tuber greening) and 90% (very strong tuber greening), being evaluated all harvested tubers.

Results and Discussion

The results showed significant effects of the factors time of ridging and spacing between plants in the row, under the production characteristics, number of tubers per plant, average weight of tubers and productivity, yet there was no occurrence of interaction between the factors.

The highest averages of the average weight of tubers were found in treatments without ridging and with realization of ridging in the planting (Table 3). Possibly this result is evidence that the realization of ridging after plant emergence causes physical damage, and also physiological, which change the normal characteristics of development of the tubers, reducing its final mass.

The average mass of the tuber increased linearly with the expansion of spacing between plants in the row, showing that the consequent reduction of density allows better conditions for growth of the tubers (Figure 1). This occurs probably due to improved environmental conditions such as broader brightness distribution and better air circulation in the shoot also having a lower competition for nutrients in the soil, improving the production of photoassimilates as observed by BURTON (1981).

The number of tubers per plant showed decreasing behavior with the increase in spacing of plants (Figure 2). Considering the figures 1 and 2, it is observed that in crops with smaller spacing the plants produce a greater number of tubers, although with smaller mass. To DELLAI et al. (2008) the decrease of average mass of tubers with the increase in number of tubers produced per unit area, is consequence of greater competition by the assimilated which tends to follow the increased density of plants.

In addition, BURTON (1981) states that it is possible for a plant with shoots less developed, due to competition, produce smaller tubers due to the reduction of the light intensity, which affects the patterns of production and distribution of assimilates in different organs of the plant. As for CALISKAN et al. (2009), the decrease in row spacing tends to cause an increase in the number of wells per unit area, resulting in the production of tubers with a smaller mass, due the increased competition between canopy growth and accumulation of reserves, resulting in lower growth of the tubers.

In this case for the production of potato consumption, where the tubers are more preferred, the best alternative would be to use smaller plant densities. Corroborating, TEIXEIRA et al. (2010) point out that in crops of tubers the consumption and the productivity resulting from higher plant densities in general did not totally compensate, because the need for greater amounts of seed potatoes and reducing the market value of the smaller size of the tubers produced. For the authors, in contrast, increased plant density may be a management strategy when the goal is the production of seed tuber, where different from the standards for consumption, are preferred smaller tubers.

Table 3. Average mass of the tuber of the potato as a function of time of ridging

Treatment	Average mass of the tuber
Ridging in the planting	136.56 a
Ridging in the 10 DAE	94.44 b
Ridging in the 20 DAE	88.41 b
Without ridging	126.39 a
DMS	**23.53**

Averages followed by the same letter do not differ significantly by Tukey test ($p < 0.05$).

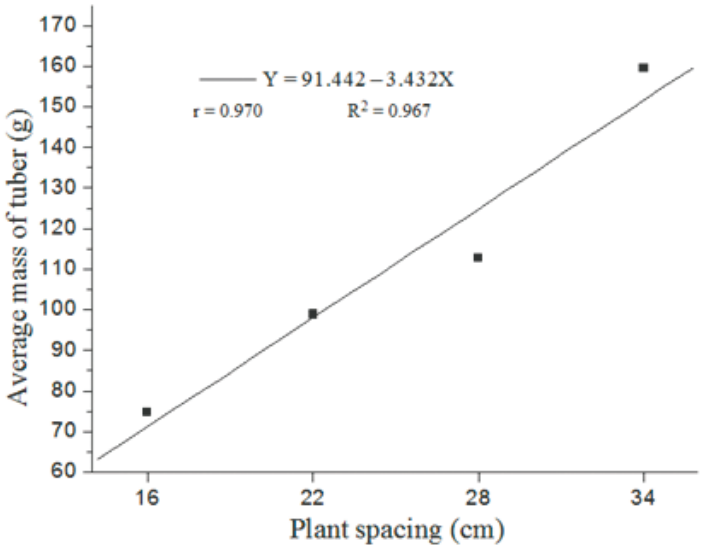

Figure 1. Average mass of tubers of potato plants as a function of plant spacing.

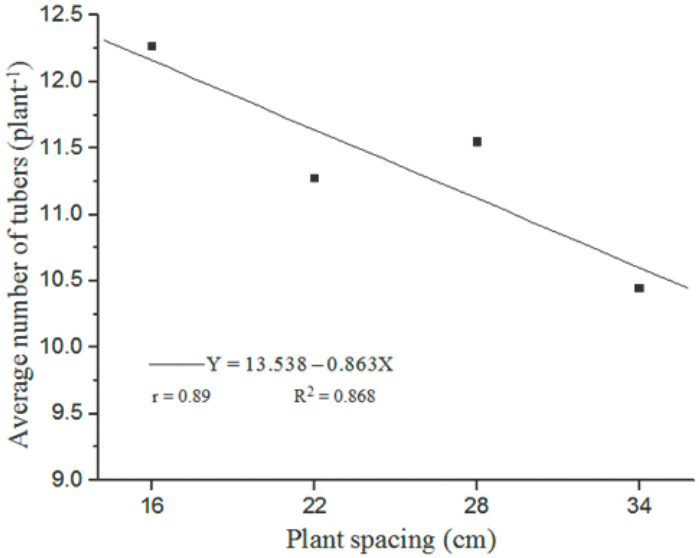

Figure 2. Number of tubers of potato plants in function of the spacing between plants.

The results presented in Table 4 demonstrate that the average number of tubers was significantly affected by the times of ridging. As observed for the average weight of tubers, plants grown under conditions of treatments without ridging and ridging at planting produced a greater number of tubers.

The overall average of 11.38 tubers per plant was lower than the average of 15 tubers to the cultivar Agate observed by FERNANDES et al. (2010). However, it is within the regional reality where JADOSKI et al. (2010) point data that show as a good production to obtain a total of approximately a dozen tubers per plant.

In these situations, there are the alternatives of ridging in the planting and the non-conduction of ridging, since they represent the possibility of reducing the movement of machinery on the crop and consequently cause mechanical damage to plants, especially in relation to late ridging 20 DAE, when the movement fatally leads to breakage of branches and leaves, and a potential increase in the spread of pathogens in the growing area.

The evaluation of the effects of seasons of performing ridging (Table 5) shows that the total productivity shows similar behavior to that observed for the components of the mass production of tubers and average number of tubers per plant, where the major averages were obtained from the ridging in the planting or by cultivation without realization of ridging, and for both, there was an increase of more than 10 t ha^{-1} in the final yield, in relation of treatments with ridging at 10 and 20 DAE.

For productivity in different plants spacing in the row it was observed the significance of a regression quadratic equation (Figure 3). By deriving this equation to the obtaining of the minimum yield point, there is a value of 49,508 kg ha^{-1} for spacing of approximately 25 cm between plants, while at end spacing of 16 and 34 cm, productivity is approximately 59,000 kg ha^{-1}.

Considering the behavior of the mean weight of tubers and number of tubers per plant in relation to intervals of plant spacing studied, it is probable that if the goal is the production of tubers for consumption, the best option is to use cultivation spacing of 34 cm between plants, which tends to result in higher productivity of tubers with presence of higher mass. These results are in agreement with TEIXEIRA et al. (2010) who describe that the greater spacing between tubers in the planting are suitable for the production of consumption potato resulting in larger tubers, in which case, consensual among producers that in this situation the greatest spacing in the planting exempts the costs of production by reducing spending on seed tubers.

The final strategy of cultivation can be set

Table 4. Average number of tubers per plant, underwent four seasons of ridging.

Treatment	N° of tubers by $plant^{-1}$
Ridging in the planting	12.11 a
Ridging in the 10 DAE	11.05 b
Ridging in the 20 DAE	10.64 b
Without ridging	11.70 a
DMS	**0.561**

Averages followed by the same letter do not differ significantly by Tukey test ($p < 0.05$).

Table 5. Average yield in t ha^{-1} of the potato plant underwent four seasons of ridging.

Treatment	Productivity (t ha^{-1})
Ridging in the planting	61.99 a
Ridging in the 10 DAE	49.49 b
Ridging in the 20 DAE	47.23 b
Without ridging	60.90 a
DMS	**10.52**

Averages followed by the same letter do not differ significantly by Tukey test ($p < 0.05$).

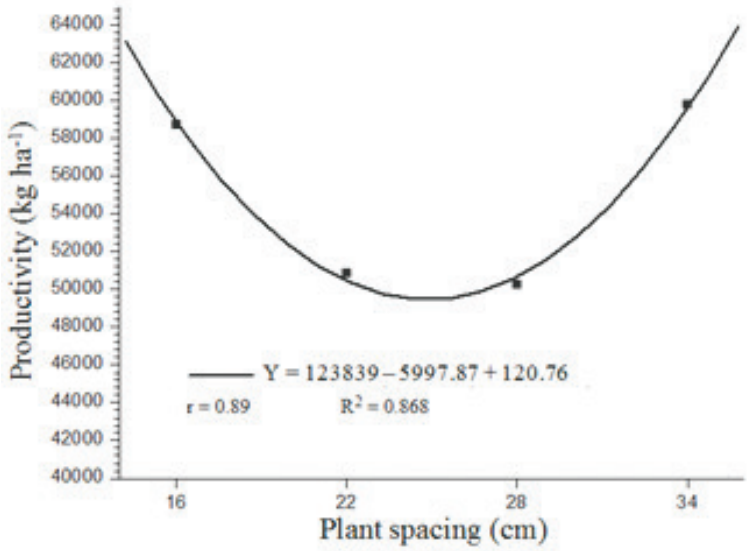

Figure 3. Productivity of potato as a function of the spacing between plants.

from the option to perform ridging in the planting or does not perform ridging, since both are the best performers of production and size of tubers. In studies conducted by HENRIKSEN et al. (2007) the practice of ridging was also dispensable under conditions in which the experiment was conducted. However, these results contradict FILGUEIRA (1999), which considers the ridging as a cultural treatment characteristic and essential to potato crop because it stimulates tuberization and increases productivity.

The highest averages of yields found in this study for both seasons of ridging as for planting spacing were close to those found by JADOSKI et al.

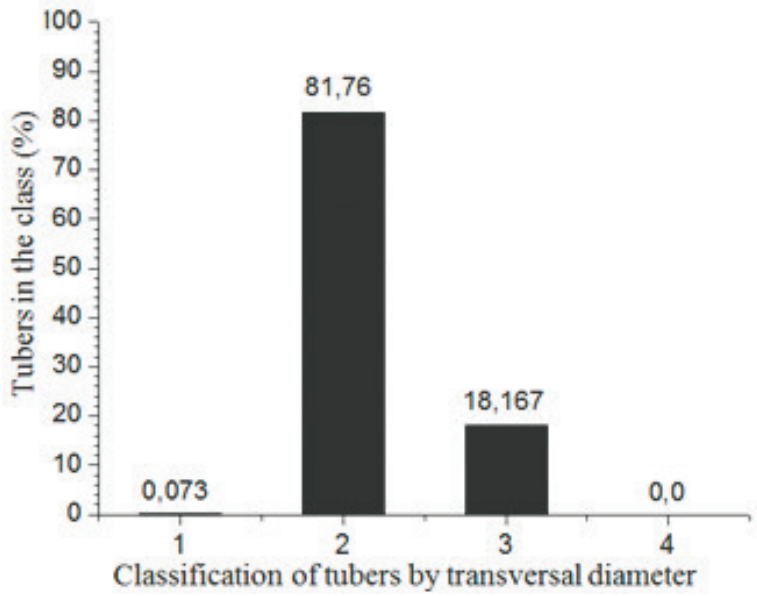

Figure 4. Classification of potato tubers grown in different spacing between plants.

(2012) for the cultivar Agata, which approximately 50 t ha^{-1}.

The average results of the classification of tubers according to the transverse diameter are presented in Figure 4. Based on the analysis of variance no significant effects were observed at the time of ridging and no interaction between factors. The spacing of plants showed significance, yet only for tubers of Class 3.

In this classification was not observed tubers in class 4 (diameter <33mm) and the average values of tubers present in class 1 (diameter> 85mm) were below 1%, these results are positive, because the class 4 has barely appropriation of commercial value. In the second class, where there were a higher percentage of tubers, the commercial valuation is full.

The insignificant presence of tubers in class 1 possibly is more related to the normal characteristics of the tubers of the cultivar Agata than necessarily to handling, as can be seen in the descriptions of MELO et al. (2003).

The percentage of tubers present in class 3 was linearly reduced with the increase in spacing of plants (Figure 5). Considering the smaller commercial valuation is interesting that the concentration of tubers in this class is reduced to the maximum in favor of classes 2 and 1. There is a reduction from 28% to 7% of the percentage of tubers present in Class 3 when the spacing between plants is 16 to 34 cm, respectively. Considering also that the total percentage of tubers in this class was approximately 18%, it is observed that it is important to manage the plantation to reduce its participation in total production.

Statistical evaluation of the tuber greening demonstrates significant effect of treatments (Table 6). It is observed that the average values for the occurrence of tuber greening were significant being close to 10%, however the intensity of tuber greening was weak, averaging less than 1%. According to NEMA et al. (2008), it is understood that low rates of tuber greening, as in this case, would still insignificant effects on palatability and flavor characteristics of potato, however, in the most demanding consumer markets or periods of high product offering these tubers can be preferably reduced.

Under the conditions of cultivation without ridging is observed that tubers had higher rates of occurrence and intensity of tuber greening, with significant differences for both parameters compared to the other treatments. This is a result that is fundamentally the most immediate effect caused by the practice of ridging, which is to increase the layer of soil on the tubers, tending to extend the period in which they remain sheltered from the direct illumination, in contrast to the effects caused by the growth of those more superficial and especially rainfall, which act by reducing the thickness of the

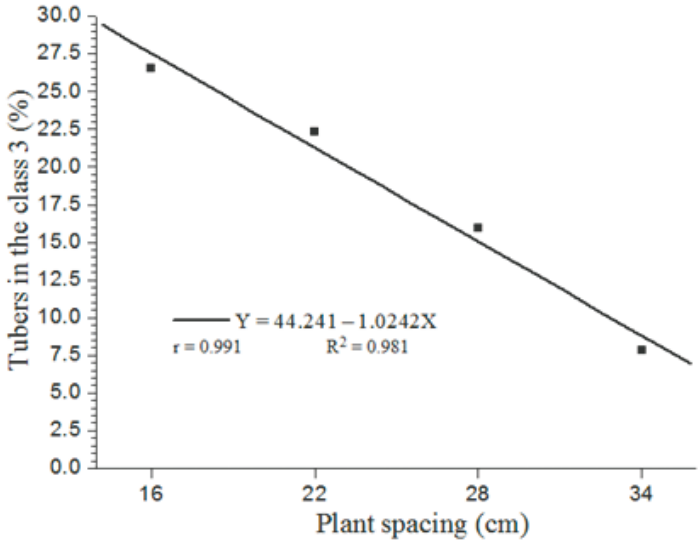

Figure 5. Percentage of potato tubers present in Class 3, as a function of spacing between plants.

Table 6. Occurrence rate and intensity of tuber greening of potato tubers subjected to four managements of ridging.

Ridging	Greening(%)	
	Occurrence	Intensity
Ridging in the planting	4.68 b	0.44 b
Ridging in the 10 DAE	5.23 b	0.34 b
Ridging in the 20 DAE	8.33 b	0.91 b
Without ridging	21.87 a	1.66 a
DMS	**6,02**	**0,82**

Averages followed by the same letter do not differ significantly by Tukey test (p <0.05).

Table 7. Results of the interaction between seasons of ridging and planting space for occurrence rate of tuber greening of tubercles.

Ridging	Spacing between plants			
	16 cm	22 cm	28 cm	34 cm
	Occurrence of greening (%)			
Ridging in the planting	2.08 bA	8.33 aA	0.001 bA	8.33 abA
Ridging in the 10 DAE	2.06 bA	6.25 aA	4.167 bA	8.30 abA
Ridging in the 20 DAE	12.49 bA	6.24 aA	10.417 abA	4.16 bA
Without ridging	35.41 aA	14.58 aB	18.750 aB	18.75 aB

Averages followed by the same lowercase in the column and uppercase in the line do not differ significantly by Tukey test (p <0.05).

soil layer on the tubers as observed HUIYUAN et al. (2012).

The evaluation of the effects of interaction between plant spacing and periods of ridging is presented in Table 7, we observe that the non-performance of ridging has the highest average of tubers with occurrence of tuber greening, with significance and in this handling the highest rate is seen in the smallest space.

These results are visually noticed even in the final stage of the crop cycle being observed that the narrowest spacing of plants had outcrop of tubers out of the ground, particularly those of smaller diameter are usually located in the stolons closest to the soil surface, condition which facilitates tuber greening by exposure to light.

In this case it can be shown that the mean that was reduced the spacing of plants, it decreased proportionally the space available in the soil for the growth of the tubers, increasing susceptibility to outcrop to the surface, a condition which becomes more evident considering that according to MELO et al. (2003) the cultivar Agata tends to a lower deep root in comparison to others potato cultivars. In this case it becomes apparent the real importance of ridging as management is massively adopted by potato producers. Confirming FILGUEIRA (1999), who describes the realization of ridging tends the non exposure the tubers to light, especially in case of rainier years or in places with soil of light texture with low clay content or low organic matter.

With the joint interpretation of these results and those inherent in the production, it appears that performing ridging is important, but not after the emergence of the plants, so the crop with greater spacing between plants associated with the realization of early ridging, stands out as the best management with crops for the production of potatoes for consumption.

Conclusions

In the range from 16 to 34cm the increasing in the plant spacing in the row cause better conditions for the production of potato for consumption, increasing the size and weight average of the tubers produced. For the production of seed potatoes should be preferred smaller spacing.

The reduction of spacing of plants increases the incidence of tuber greening by causing greater exposure to light with the outcrop of the tubers to the soil surface.

The crop yield is benefited by performing ridging before the emergence of plants.

The realization of ridging reduces the incidence of tuber greening produced.

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