English Version

Yield and sanity of potato tubers (*Solanum tuberosum* L.) under different levels of basis saturation and calcium in soil

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Abstract

The study was conducted in the experimental area of Department of Agronomy, Campus CEDETEG – UNICENTRO (State University of Midwest) in Guarapuava (PR) Brasil, 25° 23' 36" N, 51° 27' 19" W, altitude of 1025 m, and regional climate classified as Cfb (Köeppen). The aim of this study was to evaluate the effect of different levels of bases saturation and calcium in soil on the sanity, productivity and size of tubers in potato crops produced under field conditions. The planting of the potato cultivar Ágata was held on February 19th, 2009. The nine treatments were arranged in completely randomized in a 3x3, with three levels of percent bases saturation (V%) in soil (50, 60 and 70%) and each with three levels of saturation with calcium (50, 60 and 70%). It was found that the effect of soil management with 60% of bases saturation and calcium from 60 to 70% leads to higher yield and larger size of tubers. This management also leads to lower levels of severity of common scab (Streptomyces spp.). The silver scurf (Helminthosporium solani Dur. & Mont.) showed low levels of severity, and management with bases saturation of 70% and calcium from 60 to 70%, and also the management of bases saturation of 60% and calcium 50% were the most efficient alternatives to reduce the severity of this pathogen.

Key words: potato; calcium; base saturation; common scab; silver scurf.

Introduction

Potato is one of the main foods consumed in quantity in the world. In Brazil the annual average yield is approximately 15 t ha^{-1}. However, in part of the regions Southwest and South the technified producers produce more than 30 t ha^{-1} (FILGUEIRA, et al. 1995). The potato yield in developing countries is much inferior to that obtained in European countries, which have great tradition in its cultivation and high technologic levels. The European averages are above 30 to 40 t ha^{-1}. For Feltran and Lemos (2005), the level of technology used by potato producers is directly linked to the average yield obtained with the culture over the years, being one of the main criterions which cause de difference of yield between the developing countries and the European countries.

The common scab is found in all the areas which produce potato (*Solanum tuberosum* L.) of the world. According to Fisher et al. (2009) the disease is caused by Gram-positive filamentous bacteria of the genus *Streptomyces*. The species *Streptomyces scabies* (Thaxter) Waksman & Henrici is the most found causing common scab, but others as *S. acidiscabies* Lambert & Loria, *S. turgidiscabies* Takeuchi and *S. caviscabies* Goyer, Faucher and Beaulieu may cause similar symptoms of the disease. The species of *Streptomyces* which cause common scab differ by morphological, physiological and genetic criterions. For these authors, the occurrence of symptoms of deep scab depends on the resistance of the potato cultivar and on the levels of pH and soil humidity. Soils neutral to slightly alkaline are favorable to *S. scabies*, so that liming must be done carefully, so it will not exceed the pH 5.5.

The management of the nutritional characteristics of the soil is an important factor for agriculture in general. In potato crop, liming is performed mainly to provide Ca, since the level of this nutrient in soil is positively related to yield and to the quality of tubers (MIRANDA FILHO et al., 1990). For Pulz et al. (2008) the application of Ca and Mg in soil provides conditions which cause better

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development and production of the potato crop to most of the conditions of the cultivated soils.

The application of calcium in soil caused better plant development and size of tubers in work carried by Quaggio and Ramos (1986). The responses of the potato to calcium were also studied by Tawfik (2001), who observed that plants that were developed in soil with high availability of calcium tended to present highest plant development. Whereas Ozgen et al. (2006) emphasize that the application of calcium supplemental in soil may represent an important alternative to improve the quality of the tubers produced, and may also contribute to increase the crop yield.

The goal of the work was to evaluate the effect of different levels of saturation of bases and calcium in soil over the sanity, yield and size of tubers of the potato culture produced in field conditions.

Material and Methods

The research was developed in experimental area of the Faculty of Agronomy, in Cedeteg *campus* of the State University of Mid-West – Unicentro, in Guarapuava – PR, 25° 23'36"S, 51° 27'19"W, altitude of approximately 1025 m, and regional climate classified as Cfb – mesothermal humid subtropical, according to the methodology of Köeppen. The climate data of the period were obtained from the meteorological station of the University located near the experimental area.

The local soil is characteristic of the region, being classified as Latossolo Bruno Distroférrico (EMBRAPA, 2006). The chemical analysis performed in April 2008 presented the following data (layer of 0-20 cm): pH ($CaCl_2$): 4.2; M.O.: 44.3 mg dm^{-3}; P (Mehlich):1.2 mg dm^{-3}; K: 0.13 $cmol_c$ dm^{-3}; Ca: 2.0 $cmol_c$ dm^{-3}; Mg: 2.0 $cmol_c$ dm^{-3}; B: 0.25 mg dm^{-3}; Fe: 49.8 mg dm^{-3}; Cu: 1.0 mg dm^{-3}; Mn: 30.2 mg dm^{-3}; Zn: 1.4 mg dm^{-3}.

The nine treatments were distributed in experimental design completely randomized in factorial 3x3, with three levels of base saturation (V%) in soil (50, 60 and 70%) and each of these with three levels of calcium(50, 60 e 70%). In Table 1 it is presented the treatments and the quantity of calcium, gypsum and sulfur used.

To base saturation it was used limestone $CaCO_3$, PRNT approximate 90%. The addition of limestone was determined by the equation: [Liming = CTC x (V% desired – V% current) x PRNT]. The saturation of calcium was calculated by the equation: [Sat_{Ca} = (Ca_{tr}/CTC_{ef}) x 100], in which Ca_{tr} is the level of changeable calcium and CTC_{ef} is the capacity of effective cationic exchange of the soil, both in $cmol_c$ dm^{-3}. To the levels of saturation with calcium it was used agriculture gypsum [calcium sulfate dihydrate ($CaSO_4.2H_2O$)] with the formulation containing: S (14.0%), CaO (28.2%), F (0.2%) and P_2O_5 (0.7%). The presence of CaO in gypsum was calculated to the compensation of the quantity applied in the treatments and the presence of sulfur (S) was corrected by the application of sulfur in the elementary form.

Table 1 – Treatments and quantities of limestone ($CaCO_3$), gypsum ($CaSO_4.2H_2O$) and sulfur (S) used and pH conditions on the experiment of potato cultivation in Guarapuava (PR) – 2009.

Treatment	Base saturation (V%)	Saturation (Calcium)	($CaCO_3$) (t ha^{-1})	($CaSO_4.2H_2O$) (t ha^{-1})	(S) (kg ha^{-1})	initial pH	Final pH*
T2	50	50	0.87	5.47	648.2	4.30	4.65
T2	50	60	0.87	7.80	322.0	4.30	4.65
T3	50	70	0.87	10.1	0.0	4.30	4.65
T4	60	50	1.87	3.64	904.4	4.30	5.30
T5	60	60	1.87	6.00	574.0	4.30	5.30
T6	60	70	1.87	8.35	245.0	4.30	5.30
T7	70	50	2.87	1.80	1162.0	4.30	5.85
T8	70	60	2.87	4.17	830.2	4.30	5.85
T9	70	70	2.87	6.50	504.0	4.30	5.85

**pH in analysis 20 days after the harvest in layer 0 – 25 cm in soil.*

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The sowing of the potato cultivar Ágata was performed on February 19th. The seed used was Generation 01 and tubers of class II (45 to 55 mm).

Before the sowing, it was performed the soil preparation, considering the methodology normally applied by producers of the Mid-Center region of the state of Paraná, with operation of 1st harrowing, rotary tilling, 2nd harrowing, crossed scarification and scriber for ridges mounting. To the sowing, the seed-potato was manually distributed in a depth of approximately 10 cm, spacing between lines of 0.8 m and between plants of 0.25 m, with a planting density of 50,000 tubers per hectare. The application of fertilization in the furrow was of 3.5 t ha^{-1} of the formulation NPK 4-14-8. After the distribution of the tubers in the furrows it was applied fungicide with active ingredient (a. i.) Pencycuron and insecticide (a. i.) Chlorpyrifos aiming to protect tubers during the initial development.

The experimental unit had 4 lines of 4 meters of length spaced with 0.8 m with a total area of 16 m^2. It was evaluated the yield and the classification of tubers according to size and incidence and severity of Common Scab (*Streptomyces* spp.) and Silver Scurf (*Helminthosporium solani* Dur. & Mont.), over tubers. The statistic analysis was performed by analysis of variance and mean comparison test of Tukey with 95% of probability.

The classification of the tubers was effected in accordance with the classes of diameter of the law nº 69 of MAPA from February 21st, 2005 and the evaluation of the Scab was performed according to methodology proposed by Reifschneider (1987) and Azevedo (1997). The statistic analysis was based on analysis of variance and mean comparison.

During the cycle of development of plants, agricultural defensives and healings were applied considering the main fungal diseases and insects which cause damage to the culture, as well as selective herbicide (Table 2), the (a. i.) Paraquat was applied as herbicide pre-sowing and as crop desiccant (on May 24th, 95 days after planting – DAP) aiming to standardize the ending of the crop cycle and prepare of tubers for later harvest, which was held on June 19th, 2009, 121 DAP.

Results and discussion

By the evaluation of the results it was verified that the treatments applied caused different effects in the variables analyzed. The classification of the tubers considering size and total yield observed in

Table 2. Active ingredients of the products (fungicides, insecticides and herbicides) applied during the crop cycle in the experiment of potato crop in Guarapuava (PR) – 2009.

	Product (Active ingredient) – dosage (ha^{-1})*						
	Chlorpyrifos	Fipronil	Paraquat	Mancozeb	Methamidophos	λ-Cyhalothrin	Metiram
	1.5 L	35 mL	1.5 L	3 kg	100 mL	150 mL	3 kg
Month	Day of application						
March	1	23,26,27,30	6	11,13,18	18	11	23,27 30
April	-	2,10,17,20,28	-	10,17,24,30	15	-	2,6,8,1520, 28
May	-	4	24	4	-	-	-

	Product (Active ingredient) – dosage (ha^{-1})*					
	Metribuzin	Chlorfenapyr	Cypermethrina	Difenoconazole	Cimoxanil	α-Cypermethrin
	1.5 L	750 mL	150 mL	300 mL	2 kg	100 mL
Month						
March	-	-	-	-	-	-
April	7	6,8,10,17	10,2	6,7,8,30	17	8
May	-	-	-	-	-	-

**Dosage on the corresponding commertial product*

the experiments are presented in Table 3. In the classification of tubers, the results of higher yield tend to present in the intermediate range of the treatments, especially for the classes with larger diameter. To the class of tubers > 50 mm the combination V% 50 with Calcium 70 saturation and V% 60 with Calcium 50 saturation presented larger yield. To the class of tubers between 45-55 mm and also for the class 33-45 mm the combination V% 60 and Calcium saturation of 60% and 70% caused the best results. The tubers with lower diameters (< 33 mm) tended to concentrate in treatments of combination V% 70, especially V% 70 and Calcium saturation 70%.

With these results, it can be verified that the combinations studied for the base and Calcium saturation encompass the range in which the crop presents the best results. Logically, in relation to vegetal production the variations of plant responses in general demand judicious observation for making decisions and option for a certain alternative of management. In the case of this experiment, to obtain larger yield and potato tubers with larger size, the base saturation in the rage of 60% with Calcium saturation from 60 to 70% tend to be the best option of management. In similar research, Simoons and Kelling (1987) verified effect of the Calcium in the quality with the increase of the size of the tubers produced.

The yield verified inferior to 1500 bags per alqueire[1] is below what it is usually expected in the region, which generally ranges from 1500 and 2000 bags for the more technified producers, and may be superior to 2500 bags in some cases (JADOSKI et al. 2009; CARDOZO et al., 2007). However, this fact may have had as main cause the environmental factor, since sowing was performed later than it is usually practiced in the region, which has approximately February 10th as the deadline for the plantation of consume potato, due to risks of adverse weather by low temperature during the end of the cycle to later sowings. However, there is not yet an agricultural zoning for this culture in the state of Paraná (CARAMORI et al., 2003).

The evaluations of occurrence of Common Scab and Silver Scurf in tubers show effect of the treatments applied (Table 4). Silver scurf is not considered as a problem with great expression in the region and it did not manifest with great expression in the experiment. However, it is present and demands attention; therefore it must be avoided managements which may predispose increase of severity for levels of higher economic expression. In the experiment, the highest levels of base saturation tended to the occurrence of less severity of Silver Scurf.

The Common Scab, unlike Silver Scurf, is considered one of the main problems to the crop

1 1 alqueire corresponds to 2.42 hectares

Table 3. Yield and classification of potato tubers concerning the application of treatments of base and Calcium saturation management in Guarapuava (PR).

	Tubers size - production (kg ha^{-1})				Total yield		
Treatment	**> 50 mm**	**45-55 mm**	**33-45 mm**	**< 33 mm**	**(kg ha^{-1})**	**Bags ha^{-1}**	**Bags alq^{-1}**
T1	7636.7 ab	10824.2 bc	5339.8 a	304.7 ab	24105.5 b	482.1 a	1166.7 b
T2	4968.8 c	13082.0 b	3925.8 c	367.2 ab	22343.8 bc	446.9 a	1081.4 bc
T3	9117.2 a	13179.7 b	4710.9 bc	351.6 ab	27359.4 ab	547.2 a	1324.2 ab
T4	8613.3 a	11878.9 bc	6359.4 ab	378.9 ab	27230.5 ab	544.6 a	1318.0 ab
T5	8261.7 ab	15277.3 ab	6445.3 a	386.7 ab	30371.1 a	607.4 a	1470.0 a
T6	5449.2 b	16449.2 a	6714.8 a	437.5 a	29050.8 a	581.0 a	1406.1 a
T7	7406.3 ab	9492.2 c	4808.6 abc	250.0 b	21957.0 bc	439.1 a	1062.7 bc
T8	5492.2 b	14921.9 ab	5425.8 ab	554.7 a	26394.5 b	527.9 a	1277.5 b
T9	4300.8 c	10726.6 bc	5449.2 ab	152.3 c	20628.9 c	412.6 a	998.4 c

Means followeb by the same letter in column do not differ by Tukey test at 5% probability of error.

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Table 4 – Severity of Common Scab and Silver Scurf in different treatments in the experiment of cultivation of potato in Guarapuava (PR) – 2009.

Treatment	Mancha elevada	Silver Scurf	Common Scab
T1	2.70 ab	8.53 a	22.74 ab
T2	3.91a	6.26 ab	25.35 a
T3	2.29 ab	6.14 ab	25.53 a
T4	2.18 ab	6.32 ab	20.53 b
T5	1.72 b	4.64 b	15.04 c
T6	2.33 ab	6.45 ab	16.78 c
T7	2.40 ab	6.62 ab	23.34 ab
T8	2.89 ab	4.59 b	22.69 ab
T9	2.59 ab	4.09 b	22.78 ab

Means followed by the same letter in the column do not differ by Tukey test at 5% probability of error

in the region, and caused high levels of reduction in the value of the product in commerce. Through Table 4 it can be observed that the lowest severities were verified to base saturation of 60% with Calcium saturation from 60 to 70%. In the experiment the severity ranger between approximately 15 and 25%, which are expressive values, however they can be easily superior to 50%, according to what was verified by Jadoski et al. (2009). According to practical observation in the region this values can exceed rates of 70%. Fisher et al. (2009), comparing different cultivars concerning resistance to scab, verified that the cultivar Ágata was one of the less resistant among the studied presenting mean severity of 21.8%.

With the results it can be verified the positive interaction between yield and size and health of tubers, and it may be interpreted that these are characteristics affected by levels of base and Calcium saturation in soil. The best adequacy of these levels cause better development condition of tubers with higher crop yield linked to higher plant resistance to the attack of common scab, or to less appropriate conditions in soil to intensify the dissemination of the pathogen, or both. Within some limits, the occurrence of higher levels of severity of scab occurred together with larger yields, in this case, Hiltunen et at. (2005) affirm that severe infections of scab may affect expressively the yield.

Still in the results presented in Table 4 it can be seen evaluations with the name 'mancha elevada'. For this factor, it was considered injuries that are not basically classified as consequence of Scab or *Diabrotica speciosa*, which occurred with low severity and with little differences between the treatments in the experiment. This kind of injuries has called attention of researches in phytopathology and is, possibly, caused by sclerotia of the fungus *Rhizoctonia solani*. However, the fact is not completely enlightened. Thus, the referred symptoms were not counted as Scab in the results of the research.

Conclusions

For the alternatives of soil management with base saturation from 50 to 70% and calcium saturation from 50 to 70%, it may be concluded that:

Soil management with base saturation of 60% with Calcium saturation of 60 to 70% causes larger yield of the potato crop, with tubers of larger size. This management also causes lower levels of severity of Common scab (*Streptomyces* spp.).

Silver scurf (*Helminthosporium solani* Dur. & Mont.) presents low index of severity in the region of Guarapuava (PR). The management with base saturation of 70% and Calcium saturation with 60 to 70%, and also the management with base saturation of 60% and Calcium saturation with 50% were the most efficient alternatives to reduce the severity of this pathogen.

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