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CROP PRODUCTION

Does planting time affect the nutritional demand and yield of potato cultivars?

Vlandiney Eschemback[1*] Jackson Kawakami[1] Aline Marques Genú[1] Fabiola Oliveira de Almeida[1]

[1]Centro de Desenvolvimento Educacional e Tecnológico de Guarapuava (CEDETEG), Universidade Estadual do Centro-Oeste do Paraná (UNICENTRO), 85040-080, Guarapuava, PR, Brasil. E-mail: veschemback@hotmail.com. *Corresponding author.

ABSTRACT: *Determining the level of absorption of nutrients in the potato crop at different stages of development is important because it allows identification of the time when the elements are most required by plants. The objective of this research was to evaluate the level of nutrient absorption in cultivars after different planting times. Field experiment was conducted in Guarapuava-PR. Treatments consisted of three cultivars (Agata, BRS Clara, and BRS F63 Camila) and two planting times (October and February), in randomized blocks, with three replications in the crop season 2015/16. The total macro and micronutrient content (leaves, stems, and tubers) was quantified at 15 and 45 days after plant emergence. The total dry weight of plants was verified at 45 days after emergence. At harvest, dry weight of tubers, and total and commercial yield was recorded. It was observed that BRS F63 Camila produced a higher total dry weight of plants at 45 days after emergence, and higher dry weight of tubers at harvest because of the higher accumulation of Fe, Mn, and Zn following the October planting. The BRS Clara produced higher total dry weight and higher dry weight of tubers following February planting with higher Ca and S accumulation. Depending on the developmental period and planting time, cultivars differed in nutrient accumulation and tuber dry weight production. Greater nutritional demand and higher yield occurred following the October planting.*
Key words: *Solanum tuberosum, fertilization, fertility, nutrition, productivity, variety.*

Época de plantio afeta a demanda nutricional e a produtividade de cultivares de batata?

RESUMO: *Determinar a absorção de nutrientes na cultura da batata em diferentes estágios de desenvolvimento é importante pois permite identificar os tempos em que os elementos são mais exigidos pelas plantas. O objetivo deste trabalho foi avaliar a absorção de nutrientes em cultivares de batata em resposta a diferentes épocas de plantio. O experimento foi conduzido a campo em Guarapuava-PR. Os tratamentos foram constituídos de três cultivares (Ágata, BRS Clara e BRS F63 Camila) e duas épocas de plantio (outubro e fevereiro), em blocos casualizados, com três repetições. Foram avaliados os teores totais de macro e micronutrientes (folhas, hastes e tubérculo) aos 15 e 45 dias após a emergência das plantas. Quantificou-se a massa seca total das plantas aos 45 dias após a emergência e na colheita a massa seca de tubérculos, produtividade total e comercial. Observou-se que a BRS F63 Camila produziu maior massa seca total de plantas aos 45 dias após a emergência, e maior massa seca de tubérculos na colheita, devido ao maior acúmulo de Fe, Mn e Zn no plantio de outubro. A BRS Clara produziu maior massa seca total e maior massa seca de tubérculos no plantio de fevereiro com maior acúmulo de Ca e S. Dependendo do período de desenvolvimento e da época de plantio, as cultivares diferiram no acúmulo de nutrientes e na produção de massa seca de tubérculos, sendo observado no plantio de outubro, maior demanda nutricional e as maiores produtividades.*
Palavras-chave: *Solanumtu berosum, adubação, fertilidade, nutrição, rendimento, variedade.*

INTRODUCTION

Currently, in Brazil, intensive use of fertilizer is necessary to achieve higher yields of potatoes, a management strategy that can lower the economic and environmental sustainability of potato crop (SILVA et al., 2013). Potato fertilization is often performed without reference to technical criteria (soil analysis) by farmers, who only follow generic recommendations based on individual experiences, which generally differ from recommendations based on research (QUEIROZ et al., 2013). The excessive use of fertilizer can result in an increase in production cost, promotion of plant nutrient imbalance, and environmental contamination (FONTES et al., 2010).

In addition, few studies have to date generated technical recommendations for producers regarding the amount of nutrients to be used, and the fertilizer recommendation tables do not consider the

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specific characteristics of each cultivar (PAULETTI & MOTTA, 2017). However, there are studies that reported the importance of fertilizer management according to cultivar, especially for nitrogen and potassium (FERNANDES et al., 2011).

Most of the potato cultivars currently used in Brazil were developed in Europe. However, Brazilian weather and soil conditions are different from those in Europe and the effects of tropical and subtropical conditions on crops may result in inferior yield, as well as differences in nutrient absorption and accumulation (FILGUEIRA, 2011). In fact, nutrient absorption has been reported to differ between potato cultivars (FERNANDES et al., 2011). Today, domestically produced potato cultivars are currently available (PEREIRA et al., 2015), but they are not widely used and are often unknown to most Brazilian farmers. Low utilization of these cultivars is exacerbated by lack of availability of management recommendations.

Domestic cultivars may absorb nutrients in a different way than those normally used because they were bred in Brazilian soil and weather conditions. It is presumed that plants grow differently depending on planting time and consequently may differ in nutrient absorption and nutritional demand.

The objective of this research was to evaluate nutrient absorption and potato crop yield following different planting times and in different cultivars, generating information that can help farmers and researchers.

MATERIALS AND METHODS

Experiment was conducted in the 2015/16 crop season; treatments comprised 2 planting times (October and February) and 3 potato cultivars (Agata, BRS Clara, and BRS F63 Camila). The experimental design was a completely randomized block, in a split-plot scheme, with the planting time assigned to the main plots and the cultivars in the subplots, with 3 replicates. Each subplot measured 8.0 × 4.5 m, composed of 10 rows, with 18 plants in each row, with a spacing of 0.80 m between rows and 0.25 m between plants.

Type III (30 and 40 mm) seed tubers were used from cultivars BRS Clara, BRS F63 Camila, and Agata at both planting times, being homogenized for sanity and physiological age. They were stored in a cold chamber (4 °C) until approximately 40 days prior to tuber planting for both planting times.

The experiment was conducted at the experimental field in Guarapuava-PR at Midwestern Parana State University, UNICENTRO. The soil in the location (25°23′04″S; 51°29′36″E) is classified as Latossolo Bruno (very clayey Typic Hapludox) according to MICHALOVICZ et al. (2014) and the experiments planted in October and February used plots adjacent to each other. The initial soil chemical characterization of the 0.00-0.20 m layer is presented in table 1. Liming with filler dolomite limestone (PRNT 100%) was performed during the 3 months before planting in both crop seasons to reach a base saturation (V%) of 60.

Soil preparation began a month prior to the experiment implantation with one subsoiling and two harrowing. By the time of planting, which occurred on the 8th of the month for both crop seasons (October 2015 and February 2016), a light harrowing and a further furrowing of the area was made. The NPK fertilizer 04-14-08 at a dose of 4 t ha^{-1} was distributed as a total dose in the furrow immediately before manual planting of tubers. A total of 160 kg ha^{-1} of N, 560 kg ha^{-1} of P_2O_5, and 320 kg ha^{-1} of K_2O was provided, in line with the amounts of these nutrients traditionally used by crop farmers in the Guarapuava region.

Mechanical hilling was done approximately 15 days after plant emergence (DAE, approximately 20 days after planting) for both planting times. Phytosanitary management was done according to the

Table 1 - Chemical attributes of the soil before the installation of the experiment, Guarapuava-PR.

Depth	pH	P Mehlich	O. M.	K	Ca	Mg	Al	H+Al	CEC	SB	V
m	$CaCl_2$	mg dm^{-3}	g dm^{-3}	------------ cmol$_c$ dm^{-3} ------------							%
0.00 - 0.20	5.0	3.1	41.9	0.2	2.9	1.9	0.0	4.3	9.2	5.0	54
Depth		B	Cu	Fe	Mn	Zn	S		Sand	Silt	Clay
m		------------ mg dm^{-3} ------------							------ g kg^{-1} ------		
0.00 - 0.20		0.2	0.9	23	23	0.9	25		200	310	490

technical recommendation for the region (PEREIRA & DANIELS, 2003).

For the analysis of nutrient content, four whole plants that were apparently well nourished were collected from each plot. The collections were performed at the tuber formation stage, at 15 DAE, when nutrient absorption by plants started to increase and at the tuber filling stage, at 45 DAE, when plants reached a higher nutrient absorption rate (FERNANDES et al., 2010).

Plant samples were separated into leaves, stems, and tubers (roots were not used) and were subsequently washed and dried in a forced air circulation oven at 70 °C. After being weighed, the samples were ground in a Wiley mill and the levels of macro (N, P, K, CA, Mg, and S) and micronutrients (Cu, Fe, Mn, and Zn) in each plant organ were determined via the sulfuric digestion method for N and the nitric-perchloric method for the other nutrients (MALAVOLTA et al., 1997). Nutrient content for the whole plant (at each time of sampling) was defined as the sum of the weighted averages of the nutrient levels in the different organs of the plant (leaves, stems, and tubers).

Total dry weight accumulation (leaves, stems, and tubers) of the plants at 45 DAE at both planting times and the dry weight of tubers harvested were quantified for 12 plants from each plot after physiological maturation at approximately 80 DAE.

The average temperature observed during the experiment for crop season 2015/16 (21 °C) was higher than the historical average observed over the last 30 years (19 °C). During the cultivation period from October to December, there was greater precipitation (642 mm) than during the period from February to May (404 mm). Solar radiation during October (18 MJ m^{-2} day^{-1}) planting period was also greater than that during the February planting period (15 MJ m^{-2} day^{-1}); it increased during the October planting period and decreased during the February planting period (SIMEPAR, 2018).

Analysis of variance (ANOVA) and Tukey tests ($p<0.05$) were performed. When there was a significant interaction, the decomposition of the interaction was performed, and the results presented.

RESULTS

There was a difference between planting times in relation to the N content at 45 DAE (Table 2). When planted in February, plants presented higher N content; however, no significant difference was observed for N content among cultivars (Figure 1a). The P content in plants at 15 DAE exhibited an effect of planting time (Table 2) and higher content was observed for the October planting time than for the February planting time, with no difference among cultivars (Figures 1c, 1d). With regard to cultivar effects on K, it was observed at 15 DAE (Table 2) that BRS F63 Camila had a higher, BRS Clara a lower, and Agata an intermediate K content (Figure 1e) with no difference in K content at 15 DAE between planting times (Figure 1f).

There was an effect of planting time and cultivar for S at 15 DAE, with Agata presenting a higher, BRS F63 Camila a lower, and BRS Clara an intermediate content (Figure 1g). Plants accumulated more S when planted in February than when planted in October (Figure 1h).

There was a significant interaction between planting time and cultivar for Ca content in plants at 15 DAE (Table 2). A higher content for cultivar BRS Clara was observed following the February planting time, no difference was observed in Ca levels among cultivars following October planting time (Figure 3a). No effect was observed for cultivar or planting time or for their interaction on Mg content at 15 and 45 DAE (Table 2).

At 15 and 45 DAE, there was a cultivar effect on Fe content (Table 2), and at the beginning of the cycle, Agata presented higher levels of Fe (Figure 2a); however, at 45 DAE, BRS F63 Camila had the highest total content of this nutrient, BRS Clara the lowest, and Agata had an intermediate value (Figure 2c). For Mn, at 15 and 45 DAE, there was an interaction between cultivar and planting time (Table 2). BRS F63 Camila presented higher Mn content following the October planting time (Figure 3c) and at 45 DAE BRS F63 Camila had a lower content of this nutrient, and the Agata and BRS Clara cultivars had higher Mn levels; although, this difference was not significant (Figure 3d).

A difference in Cu levels at planting times was observed at both 15 and 45 DAE (Table 2). At both sampling time, following the October planting time, the cultivars accumulated higher Cu content (Figures 2f and 2h). No differences were observed among cultivars for Cu content (Figures 2e and 2g). For Zn content, there was an interaction between planting time and cultivar at 15 and 45 DAE (Table 2). At the beginning of the cycle, BRS F63 Camila presented a higher level of this nutrient following the October planting time, and Agata and BRS Clara cultivars had lower content (Figure 3e); at 45 DAE, the same tendency was observed among cultivars for the February planting time (Figure 3f).

Table 2 - P-value of the analysis of variance of the variables evaluated in potato plants as a function of planting time (Time) and cultivars at two different days after emergence (DAE) of the plants. Guarapuava-PR.

P-value	Time	CV 1 (%)	Cultivar	Time x Cultivar	CV 2 (%)
N[1]	0.086	10.1	0.377	0.231	9.3
P	**0.008**	3.5	0.326	0.390	7.6
K	0.272	3.5	**0.041**	0.156	8.0
Ca	0.155	14.7	**0.005**	**0.040**	7.6
Mg	0.411	7.7	0.333	0.626	6.2
S	**0.030**	10.7	**0.023**	0.053	7.5
Fe	0.298	8.4	**0.007**	0.070	18.8
Mn	0.586	32.7	**0.039**	**<0.001**	17.4
Cu	**0.028**	28.6	0.357	0.512	40.5
Zn	**0.008**	9.7	0.075	**0.016**	9.5
Total plant DW	0.360	42.9	0.874	0.297	17.4
---45 DAE---					
N	**0.030**	16.0	0.523	0.166	7.5
P	0.518	15.3	0.317	0.772	8.0
K	0.352	13.6	0.073	0.681	9.4
Ca	0.176	14.6	0.079	0.926	14.3
Mg	0.178	2.5	0.845	0.899	5.2
S	0.057	7.9	0.899	0.963	11.0
Fe	0.703	34.5	**0.032**	0.099	25.9
Mn	0.097	22.6	0.081	**0.007**	18.9
Cu	**<0.001**	1.8	0.453	0.606	36.1
Zn	**0.020**	9.9	0.700	**0.002**	12.9
Total plant DW	**0.029**	32.2	**0.003**	**0.045**	23.7
---Harvest---					
Tuber DW	**0.003**	9.72	**<0.001**	**0.048**	16.22
Total yield	**0.016**	11.90	**<0.001**	0.067	18.10
Commercial yield	**0.007**	14.10	**<0.001**	**0.023**	19.50

[1]Nitrogen (N), Phosphorous (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulfur (S), Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn), total plant dry weight (DW), tuber DW and total and commercial tuber fresh yields. CV: coefficient of variation.

Interactions between planting time and cultivar were observed at 45 DAE for plant total dry weight (Table 2). Following the October planting time, BRS F63 Camila accumulated a greater total dry weight. Agata had the lowest value and BRS Clara an intermediate value for total dry weight accumulation (Figure 4a). Following the February planting time, BRS Clara had a greater total dry weight, and Agata and BRS F63 Camila cultivars had lower accumulations (Figure 4a). It was observed that following the October planting time, BRS F63 Camila and BRS Clara accumulated a greater total dry weight than following the February planting time. No difference was observed for total dry weight for Agata when planted in October and in February.

BRS F63 Camila accumulated greater dry weight in tubers following the October planting time and BRS Clara had a greater accumulation in the tubers when planted in February. When plants were planted in October, there was greater dry weight accumulation in the tubers for all cultivars than when they were planted in February (Figure 4b).

An interaction effect between planting time and cultivars (Table 1) was observed for total yield. In October planting time, BRS Camila had a higher yield and there was no difference between Agata and BRS Clara (Figure 5a). In February planting, BRS Clara had a higher yield than the Agata and BRS F63 Camila cultivars, which had an intermediate yield (Figure 5a). The same tendency was observed for commercial yield (Figure 5b). In general, the new cultivars were more productive than Agata, regardless of planting time, and higher yields occurred when planted in October.

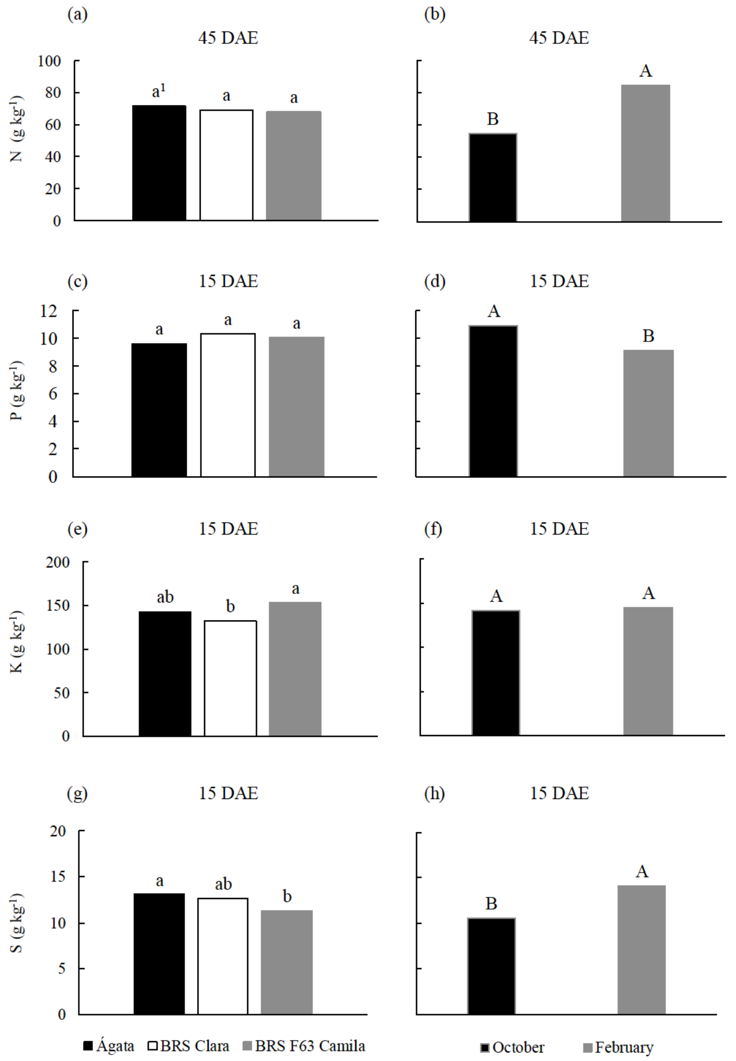

Figure 1 - Nitrogen (N; a, b), phosphorus (P; c, d), potassium (K; e, f) and sulfur (S; g, h) contents in cultivars and planting time, at 15 and 45 days after emergence (DAE). Guarapuava-PR.

[1]Means followed by the same lowercase letter (among cultivars) and uppercase (between planting time), did not differ significantly by Tukey's test (P<0.05).

DISCUSSION

According to Fernandes & Soratto (2013), the primary macronutrient content in potato plants did not differ among cultivars evaluated. However, a difference in the nutrient absorption following the different planting times was observed, with plants having higher nutrient absorbance following October planting time.

Among the macronutrients, only K and Ca differed among the studied cultivars, with BRS F63 Camila having a higher and BRS Clara a lower K content (Figure 1e). The Ca content was higher in BRS Clara at 15 DAE following the February planting time (Figure 3a). Excessive K content could lead to decreased osmotic potential and increased water absorption, causing dilution of the dry weight in the tubers (PAULETTI & MENARIN, 2004; CARDOSO et al., 2007). This effect was not observed in the present study because the BRS F63 Camila cultivar presented higher production of total and tuber dry weight following the October planting time

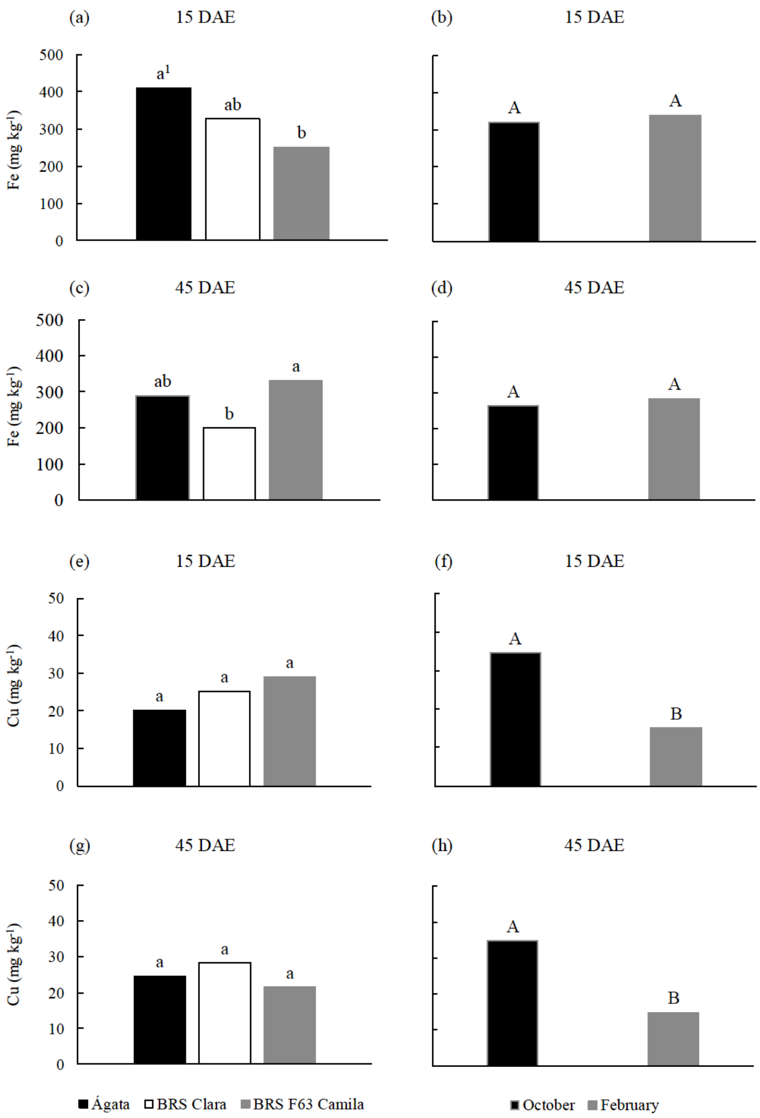

Figure 2 - Iron (Fe; a, b, c, d) and copper (Cu; e, f, g, h) contents in cultivars and planting time, at 15 and 45 days after emergence (DAE). Guarapuava-PR.

[1]Means followed by the same lowercase letter (among cultivars) and uppercase (between planting time), did not differ significantly by Tukey's test (P <0.05).

(Figure 4a, 4b). That is, the K content in this cultivar did not negatively interfere with the total dry weight production and tuber yield.

Higher nutrient content was observed in the cultivars following the October planting time probably because of the higher amount of precipitation that occurred during this period than that in the February planting time; the latter planting time had lower precipitation and plants presented the lowest nutrient levels (SOARES et al., 2008).

The higher absorption rate period occurred at the beginning of the tuber filling phase in all potato cultivars studied, i.e., when the amount of nutrients absorbed by the plants began to increase rapidly, coinciding with the higher dry weight production rate period (FERNANDES, 2011). Thus, it is likely that with good water availability and adequate temperature and solar radiation, these plants absorb more water and nutrients followings the October planting time, leading to greater accumulation in

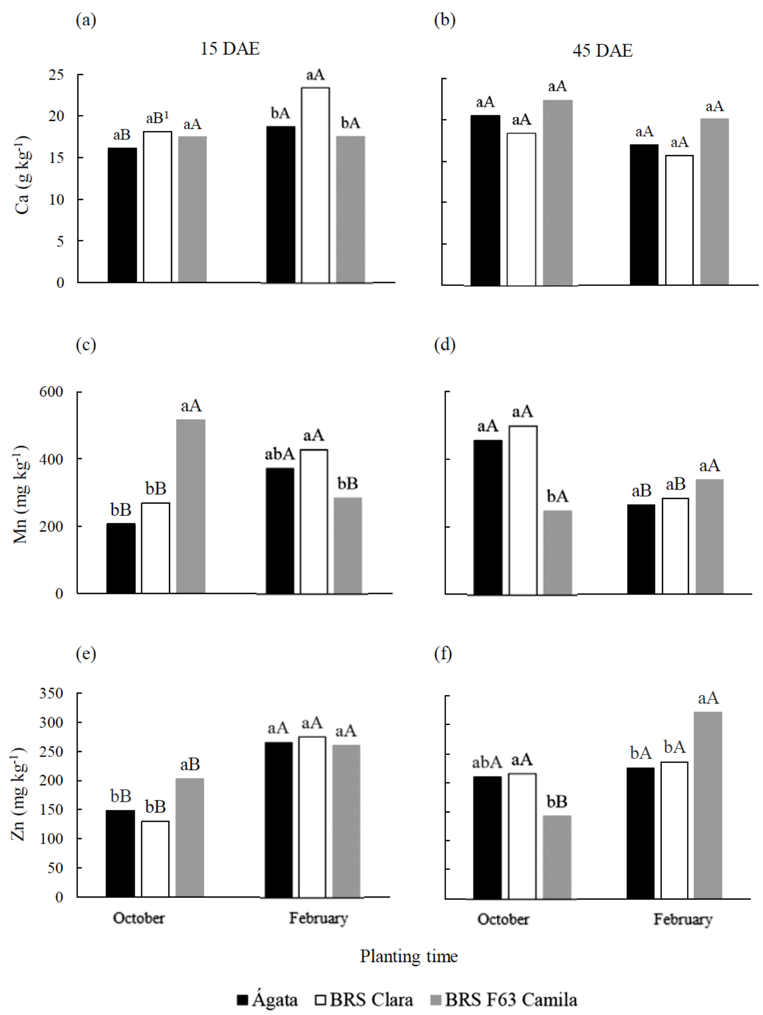

Figure 3 - Calcium (Ca; a, b), Manganese (Mn; c, d) and Zinc (Zn; e, f) contents at 15 and 30 days after emergence (DAE). Guarapuava-PR.

[1]Means followed by the same lowercase letter (among cultivars) and uppercase (between planting time), did not differ significantly by Tukey's test (P <0.05).

tubers and total dry weight in comparison to the February planting time.

A study reported that the BRS Clara cultivar has a tolerance to low water content in the soil under field conditions (SILVA et al., 2013). Following the February planting time, a higher tuber dry weight production was observed for this cultivar. At the same time, higher Ca content for BRS Clara was observed following this planting time. One of the main functions of Ca, which is essential for cellular division, is root system growth, development, and function (MALAVOLTA, 2006). Thus, the highest Ca content noted in the present study could be a favorable characteristic of this cultivar during periods of low water content in the soil.

The BRS F63 Camila cultivar produced a higher amount of dry weight at the October planting time because of greater extent of absorption of some nutrients, such as Fe, Mn, Zn, and K. The metabolic use efficiency of these nutrients may be greater at this planting time, leading to a higher total plant and tuber dry weight (FERNANDES et al., 2010).

The highest total and tuber dry weight production of BRS F63 Camila cultivar following the October planting time and of BRS Clara following the February planting time was probably because the

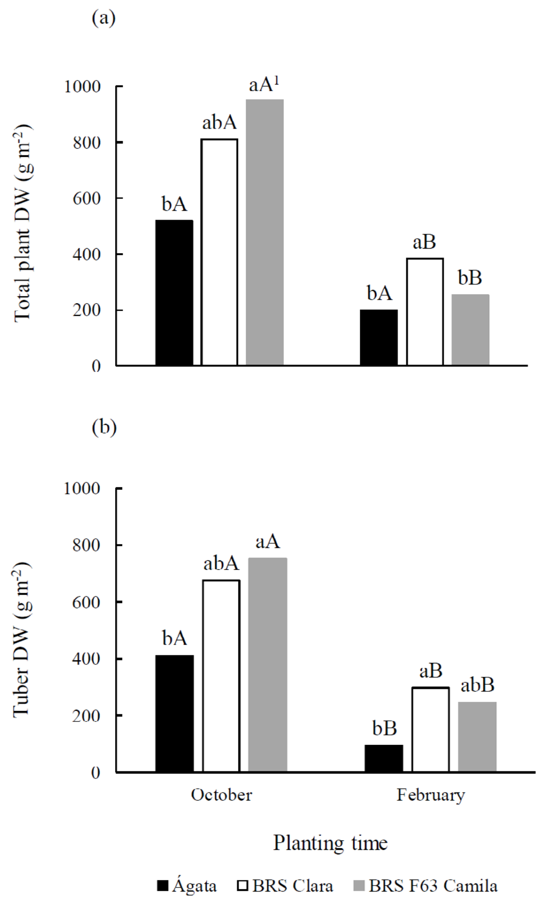

Figure 4 - Total plant dry weight at 45 DAE (a) and tuber dry weight at harvest (b) in cultivars and planting times, Guarapuava-PR.

[1]Means followed by the same lowercase letter (among cultivars) and uppercase (between planting time), did not differ significantly by Tukey's test (P <0.05).

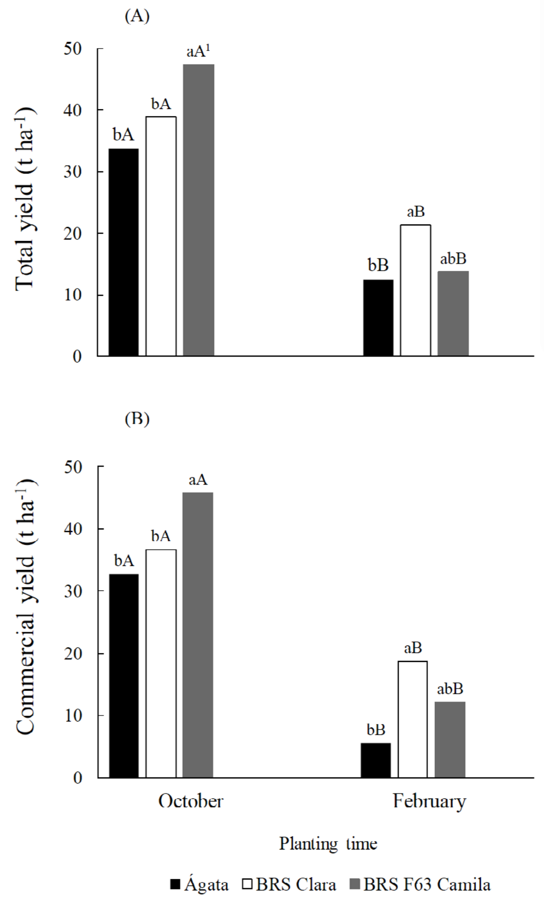

Figure 5 - Total yield (a) and commercial yield (b) at harvest in cultivars and planting time, Guarapuava-PR.

[1]Means followed by the same lowercase letter (among cultivars) and uppercase (between planting time), did not differ significantly by Tukey's test (P<0.05).

domestic cultivars were more adapted to the soil and cultivation conditions, being more efficient in nutrient utilization, and consequently, more productive; or they experienced greater nutrient conversion into biomass because of rapid assimilation or greater efficiency in internal cycling capacity (FONTES et al., 2010).

In general, plant macronutrient content did not differ among cultivars. However, Cu and Zn absorption by the cultivars was greater in the final period of tuber filling and during the maturation period (FERNANDES & SORATTO, 2013).

A difference in yield and nutrient content among the cultivars studied was observed, depending on the planting time and period of plant development. In another study, BRS Clara had a total yield of 18,900 kg ha^{-1} and commercial yield of 11,000 kg ha^{-1} (PEREIRA et al., 2013). In the same study, Agata produced 13,300 kg ha^{-1} of total tubers and 7,400 kg ha^{-1} of commercial tubers. The yield values observed in this study were close to those observed in another study (ESCHEMBACK et al., 2017). These values were similar to those obtained for the cultivars following the February planting time but inferior to those observed during the October planting time. The favorable weather conditions that occurred following the October planting time contributed to the higher yield and nutrient absorption of these cultivars than that following the February planting time.

It was verified that the new cultivars absorbed more nutrients than did the Agata cultivar, which has been traditionally used by farmers following both planting times. This may be related to better adaptation of these cultivars to the Brazilian soil and cultivation system. However, the difference in nutrient absorption between planting times is usually not taken into account in the fertilizer recommendations for potato crops (PAULETTI & MOTTA, 2017). Based on the results observed in the present study, for the planting time during the dry crop season (February planting time), we recommended the use of a smaller amount of fertilizer for the potato crop because of the lower nutritional demand and yield during this planting time.

CONCLUSION

A difference in nutrient absorption depending on the plant development period was reported and nutrient content varied among cultivars depending on the planting time. Regarding fertilizer recommendations for the potato crops, it is necessary to consider the planting time when determining the amount of nutrient input required because the cultivars have different nutritional demands depending on when they are cultivated. It was verified that domestic cultivars had higher tuber yield than that of Agata, regardless of planting time, and the highest yields were achieved when the crops were planted in October.

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DECLARATION OF CONFLICT OF INTERESTS

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the samplings, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

VE and JK conceived and designed the experiments, performed statistical analyses of experimental data, prepared the draft of the manuscript, critically revised and approved the final version. VE, FOA performed the field experiments and the laboratory analyses. AMG supervised and coordinated the laboratory analyses, prepared the draft of the manuscript, critically revised and approved the final version.

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