



DOI: <http://dx.doi.org/10.1590/1807-1929/agriambi.v24n3p176-186>

Dry matter and macronutrient extraction curves of potato varieties in the Alto Paranaíba region, Brazil

Carlos D. da Silva¹, Maria E. P. Soares¹, Miller H. Ferreira¹, Alian C. P. Cavalcante²,
Guilherme A. V. de Andrade³ & Leonardo A. de Aquino¹

¹ Universidade Federal de Viçosa/Pós-Graduação em Produção Vegetal, Rio Paranaíba, MG, Brasil. E-mail: carlosdiego_agro@hotmail.com (Corresponding author) - ORCID: 0000-0003-4674-8455; maria.paraguassu@gmail.com - ORCID: 0000-0002-0755-065X; miller1henrique2@gmail.com - ORCID: 0000-0002-3932-9810; aquino.ufv@gmail.com - ORCID: 0000-0002-7764-730X

² Universidade Federal de Viçosa/Pós-Graduação em Fitotecnia, Viçosa, MG, Brasil. E-mail: cassio.alian216@gmail.com - ORCID: 0000-0002-7577-5607

³ Universidade Federal de Lavras/Pós-Graduação em Fitotecnia, Lavras, MG, Brasil. E-mail: guilhermeandrade@hotmail.com - ORCID: 0000-0002-1287-8369

ABSTRACT: Information on plant nutrient extraction is of utmost importance for the management of fertilization in crops. The objective of the study was to determine the accumulation of dry matter mass in the tubers and aerial parts of the plants and to generate absorption curves of macronutrients N, P, K, Ca and Mg for the potato varieties Ágata, Asterix, Atlantic and Taurus. The shoot and tuber samples were collected at 6, 13, 54, 66, 70, 82 and 97 days after planting. The highest accumulation of dry matter was observed in the Asterix and Atlantic varieties. The varieties Asterix and Atlantic showed higher N and K extraction and, consequently, higher productivity, while Taurus and Ágata presented lower yields and nutrient extraction. The period of greatest demand for macronutrients for the varieties studied is during the tuber filling phase (40 days after plantation). The variation between potato varieties in macronutrient extraction indicates a need for differential management fertilization of the plants.

Key words: *Solanum tuberosum*, absorption, nutrients

Matéria seca e curvas de extração de macronutrientes de variedades de batata na região do Alto Paranaíba, Brasil

RESUMO: Informações sobre extração de nutrientes pelas plantas são de extrema importância para o manejo da fertilização nas lavouras. O objetivo do trabalho foi determinar o acúmulo de matéria seca nos tubérculos e partes aéreas das plantas e gerar curvas de absorção para os macronutrientes N, P, K, Ca e Mg para as variedades de batata Ágata, Asterix, Atlantic e Taurus. As amostras da parte aérea e tubérculos foram coletadas aos 6, 13, 54, 66, 70, 82 e 97 dias após o plantio. O maior acúmulo de matéria seca foi observado nas variedades Asterix e Atlantic. As variedades Asterix e Atlantic apresentaram maior extração de N e K e, consequentemente, maior produtividade, enquanto Taurus e Ágata apresentaram menores rendimentos e extração de nutrientes. O período de maior demanda por macronutrientes para as variedades estudadas é durante a fase de enchimento dos tubérculos (40 dias após o plantio). A variação entre variedades de batata na extração de macronutrientes indica a necessidade de manejo diferenciado da adubação de plantas.

Palavras-chave: *Solanum tuberosum*, absorção, nutrientes



INTRODUCTION

The potato is considered a culture demanding in nutrients (Fernandes et al., 2011), and many farmers apply fertilizer doses higher than those recommended by research, which raises production costs (Nava et al., 2007).

One of the reasons why farmers use high doses of fertilizers is the use of tables with lagged information, such as the "5th Approach" (Ribeiro et al., 1999). Another issue is that the tables do not account for the genetic differences between varieties. Genetic characteristics of different varieties, as well as the cultivation system, are responsible for altering the extraction and export of nutrients, and knowing the nutritional demands of each variety is important to making nutrient recommendations (Aquino et al., 2015).

Fertilizer recommendations, generally, follow a standard, where nutrients such as N and K are applied in planting and cover, and P is recommended to be applied 100% in the planting groove (Fernandes et al., 2011). It is important that nutrients are available during the period of higher plant demand, which thus determines the best application time at the period of greatest extraction (Moreira et al., 2011).

A tool that assists in the determination of adequate nutrient and ideal timing of application is the nutrient absorption curve by plants (Mendoza-Cortez et al., 2013). Absorption curves must be generated taking into account the accumulation of degree days, and not just the count of days, after planting, so that they can be reproduced when crops are grown under different climatic conditions that influence cycle duration, especially factors such as average temperature (Renato et al., 2013).

Therefore, the objective of this study was to generate growth and macronutrient extraction curves for the potato varieties.

MATERIAL AND METHODS

The experiment was conducted from June to September 2016 at the Instituto de Pesquisa Agrícola do Cerrado (IPACER) located in the city of Rio Paranaíba, MG, Brazil (19° 12' 07.1" S, 46° 09' 21.2" W, with altitude of 1.066 m). The climate of the region is classified as Cwa, humid temperate with dry winter and hot summer (Figure 1); the rainy season is concentrated from October to March (Alvares et al., 2013).

The soil in which the experiment was carried out is classified as Oxisol of very clayey texture. The chemical composition of the soil was analyzed prior to the start of the experiment, and it had pH (H₂O): 5,9; P available: 2,5 mg dm⁻³; K: 38 mg dm⁻³; S: 26 mg dm⁻³; B: 0,27 mg dm⁻³; Fe: 40 mg dm⁻³; Mn: 19,8 mg dm⁻³; Cu: 5,6 mg dm⁻³; Zn: 2,1 mg dm⁻³; Ca²⁺: 5,0 cmol_c dm⁻³; Mg²⁺: 1,0 cmol_c dm⁻³; P remaining: 15,3 mg L⁻¹.

The experiment was installed in randomized blocks, in which the treatments were arranged in a 2 x 4 factorial scheme with four repetitions, and consisted of the combination of two doses of fertilization (high fertilization and low fertilization) and four varieties of potato (Ágata, Asterix, Atlantic and Taurus). Fertilizer doses were defined based on potato crop demand. The high fertilization treatment consisted of 100 kg ha⁻¹ of N, 980 kg ha⁻¹ of P₂O₅ and 156 kg ha⁻¹ of K₂O at planting, 80 kg ha⁻¹ of N and 156 kg ha⁻¹ of K₂O in the heap, and one more topdressing fertilizer with 156 kg ha⁻¹ of K₂O. For the low fertilization treatment, it was used 100, 500 and 156 kg ha⁻¹ of N, P₂O₅, and K₂O, respectively, at planting, and 156 kg ha⁻¹ of K₂O in the pile.

Fertilization in the heap was carried out 20 days after the planting (DAP), for both low and high fertilization treatments. At 57 DAP, fertilization was performed using K in the high fertilization treatment. These two fertilization

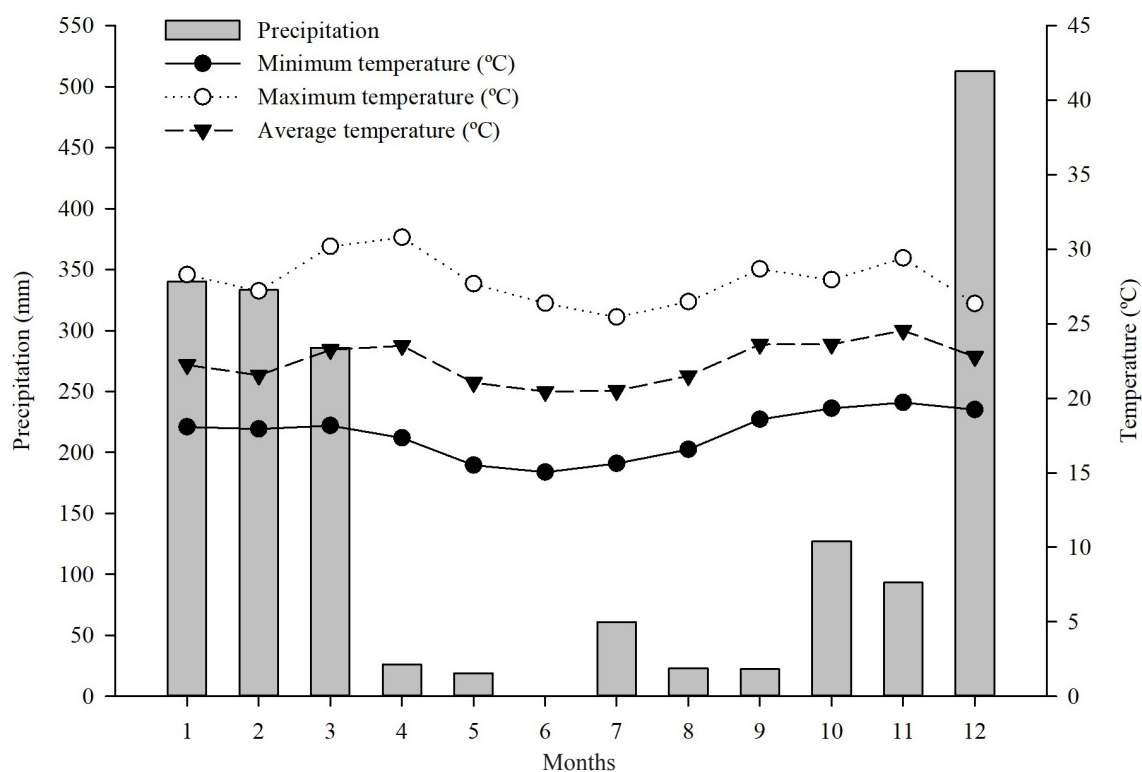


Figure 1. Maximum, average and minimum temperatures and monthly rainfall, average of the year 2016 in Rio Paranaíba, MG, Brazil

conditions were used to allow the study of absorption curves under simulated low and high nutrient availability conditions.

All varieties were planted on 08/06/16 and harvested on 28/09/16. The plots consisted of three rows, each one with 5 m in length, and the central line was considered as the useful area from which samples were taken. The line spacing was 85 cm and 35 cm between the plants. Seven sample collection dates were established at 6, 13, 54, 66, 70, 82 and 97 days after planting, where six plants per plot were collected. The samples were separated into aerial and tuber parts soon afterwards, and were weighed to estimate fresh matter (FM) in kg ha^{-1} . The samples were dried in an oven at 70 °C for 72 h and then weighed to evaluate dry matter (DM), which was associated with data on collection time. Samples were ground in a Willey mill and the N, P, K, Ca and Mg macronutrients were determined according to methods described by Miyazawa (2009). Using nutrient concentration information, it was calculated the accumulation of each nutrient in the aerial part and in the tuber of each variety along the collection dates, which were later transformed into degrees day calculated using the following equation:

$$\text{Degrees day} = \frac{(\text{maximum temperature} + \text{minimum temperature})}{2} - 7 \quad (1)$$

In calculating the degrees day, the value 7 °C represents the potato base temperature in degrees Celsius (Paula et al., 2005). The maximum and minimum temperature data for this calculation were derived from the meteorological station of the Guaxupé Regional Coffee Growers Cooperative of Rio Paranaíba, MG, Brazil, which is located 6 km from the experimental area and at the same altitude. Degrees day were calculated so that the effects of climatic conditions in the assay, especially temperature, are minimized by extrapolating the results to other growing conditions.

Graphs were generated from the nutrient accumulation data to verify the extraction and export rates by the different potato varieties used in this study. Data were analyzed using analysis of variance and the effect of treatment interactions was compared using the SNK (Student-Newman-Keuls) test at $p \leq 0.10$.

RESULTS AND DISCUSSION

The accumulation of dry matter in the shoot was more pronounced in the initial phase of development, between 600 and 1000 degrees days. From tuberization, there was reduction of growth in the aerial part, in detriment of the growth in the tubers (Figure 2).

In the initial stage of development, the potato uses photoassimilates for vegetative growth, and development of the roots and of the aerial part, and after this stage, it employs remobilization of the assimilates of these tissues for the formation of tubers (Cabalceta et al., 2005).

The phase of greatest accumulation of dry matter in tubers occurred from 55 DAP, corroborating the results of Fernandes et al. (2010). The dry matter accumulations in the tubers up to 55 days after planting of the varieties used

in the experiment were: 36% for the high fertilizer Agata variety, 35% for low fertilizer Agata, 50% for high fertilizer Asterix, 48% for high fertilizer Asterix in low fertilization, 37% for Atlantic in high fertilization, 46% for Atlantic in low manure, 45% for Taurus in high fertilization and 51% for Taurus in low fertilization. The highest accumulation of tuber dry matter was observed in the Asterix variety, both in low and high fertilization regimens, with 10.564 and 12.136 kg ha^{-1} , respectively (Figure 2). The total dry matter accumulation in the varieties used in the experiment were: Agata high fertilization 7853 kg ha^{-1} , Agata low fertilization 7941 kg ha^{-1} , Asterix high fertilization 6440 kg ha^{-1} , Asterix low fertilization 5551 kg ha^{-1} , Atlantic high fertilization 4936 kg ha^{-1} , Atlantic low fertilization 5331 kg ha^{-1} , Taurus high fertilization 3955 kg ha^{-1} and Taurus low fertilization 4745 kg ha^{-1} . The Asterix variety shows better leaf arrangement in the canopy of plants and a higher number of stems per plant, which favors interception of light and reduces the self-shading of the lower leaves, increasing the accumulation of dry matter (Fernandes et al., 2010).

The Asterix and Atlantic varieties accumulated the largest amount of N under low and high fertilization conditions, with 179 and 178 kg ha^{-1} in low fertilization and 180 and 161 kg ha^{-1} in high fertilization, respectively. In the aerial part, both varieties accumulated 35 kg ha^{-1} , and, in the tubers, they accumulated 144 and 143 kg ha^{-1} , respectively (Figure 3).

These two varieties also obtained the greatest accumulation of dry matter (DM), which explains the greater accumulation of N (Figure 2). Under high fertilization conditions, the varieties Asterix accumulated 228 kg ha^{-1} of N. The lowest accumulations of N were verified in the Taurus variety at low fertilization, with 137 kg ha^{-1} , and, in the high fertilization condition, the Ágata variety presented the lowest accumulation of N with 140 kg ha^{-1} (Figure 3).

Cardoso et al. (2007), in a study that aimed to evaluate three doses of N and K, starting with what is considered the ideal dose (140 kg of N and 280 kg of K), 75 and 125% of the ideal dose, obtained larger tubers and, consequently, higher productivity. This shows the importance of properly managing fertilization with N and K, because the low fertilization condition in the present study did not allow the same productivity as the treatment with greater fertilization.

The highest accumulation of P, both in the low and high fertilization treatments, occurred in the variety Asterix, with accumulations of 65 and 52 kg ha^{-1} , respectively. This variety accumulated, in the aerial part, 9 and 5 kg ha^{-1} in the high and in the low fertilization treatments, respectively, and, in the tubers, 56 and 47 kg ha^{-1} of P, respectively. The varieties Ágata and Atlantic accumulated the lowest amount of P at the low fertilization, 39 kg ha^{-1} each, and at the high fertilization, the lowest accumulation was observed in the Ágata cultivar, which accumulated 48 kg ha^{-1} (Figure 4).

In a study with five potato varieties (Agata, Asterix, Atlantic, Markies and Mondial) under low phosphorus doses (15 mg dm^{-3}) and high phosphorus doses (150 mg dm^{-3}), there were differences in the accumulation of this nutrient at both doses of availability and between varieties. Mondial and Agata varieties showed high yields of tuber production at both phosphorus doses. At the highest dose of phosphorus, Asterix varieties were

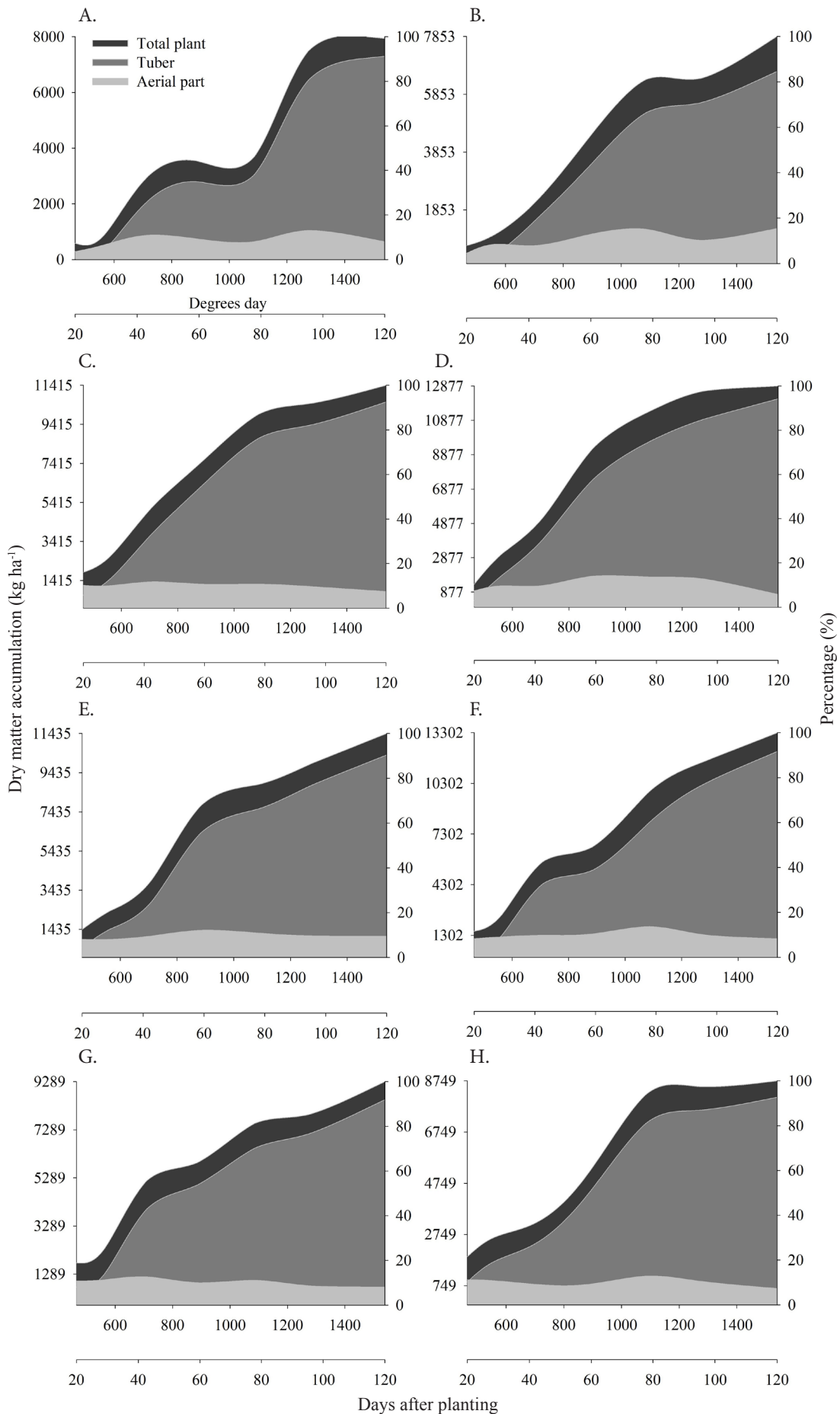


Figure 2. Dry matter accumulation in the tubers and shoot during the cycle of the varieties Ágata under low (A) and high fertilization (B), Asterix under low (C) and high fertilization (D), Atlantic under low (E) and high fertilization (F), Taurus under low (G) and high fertilization (H)

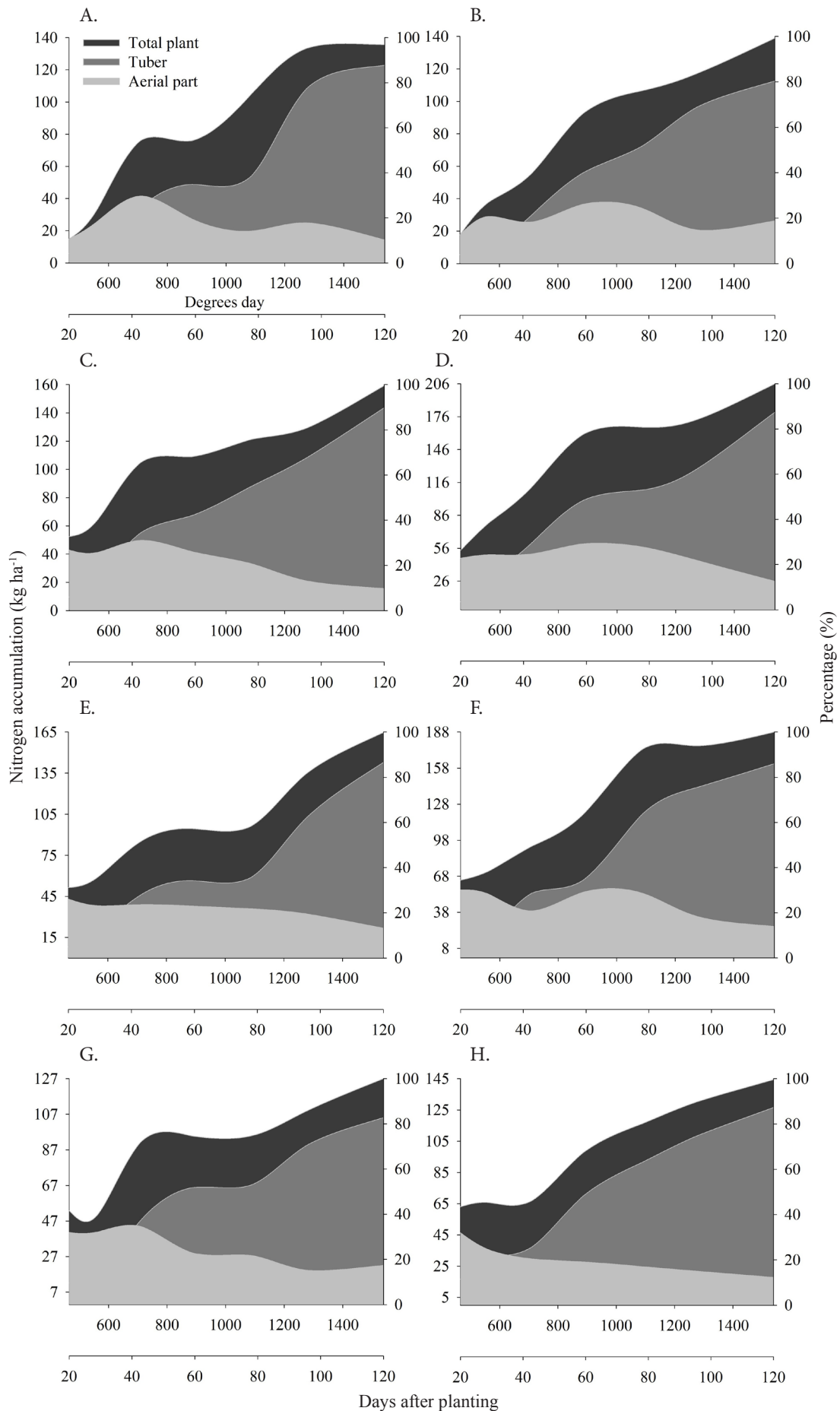


Figure 3. Nitrogen accumulation in the tubers and in the aerial part during the cycle of the varieties Ágata under low (A) and high fertilization (B), Asterix under low (C) and high fertilization (D), Atlantic under low (E) and high fertilization (F), Taurus under low (G) and high fertilization (H)

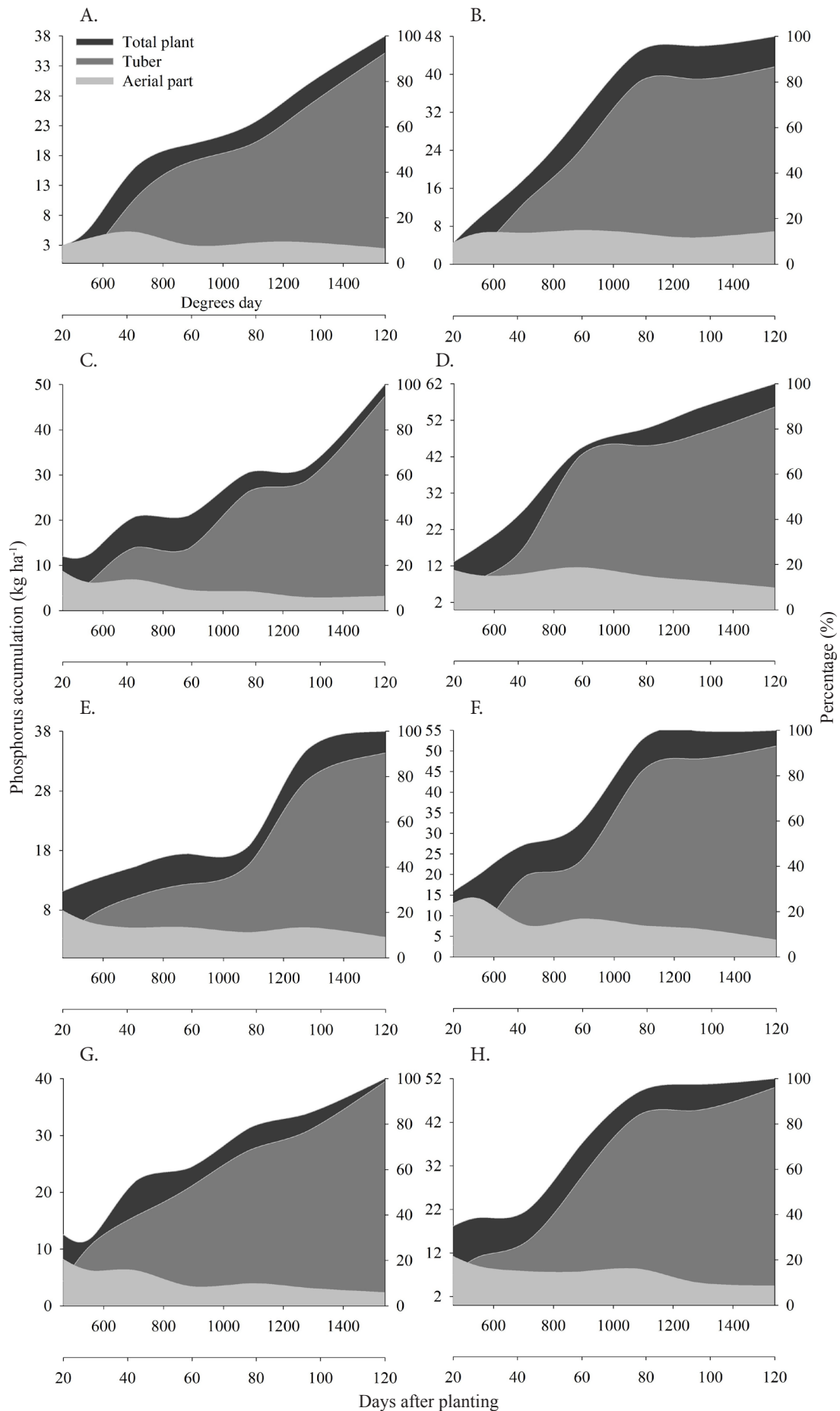


Figure 4. Phosphorus accumulation in tubers and shoot during the cycle of the varieties Ágata under low (A) and high fertilization (B), Asterix under low (C) and high fertilization (D), Atlantic under low (E) and high fertilization (F), Taurus under low (G) and high fertilization (H)

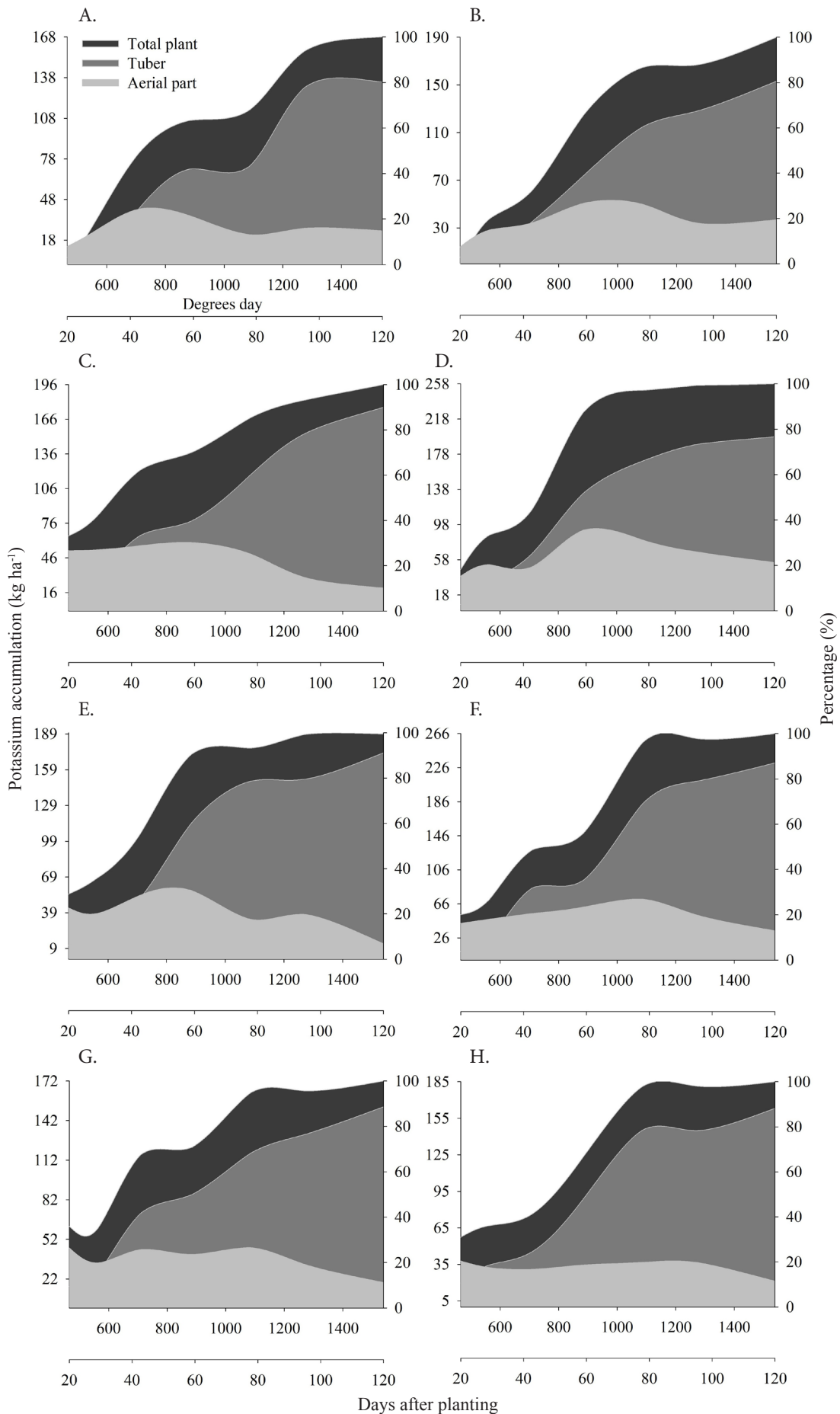


Figure 5. Potassium accumulation in the tubers and shoot during the cycle of the varieties Ágata under low (A) and high fertilization (B), Asterix under low (C) and high fertilization (D), Atlantic under low (E) and high fertilization (F), Taurus under low (G) and high fertilization (H)

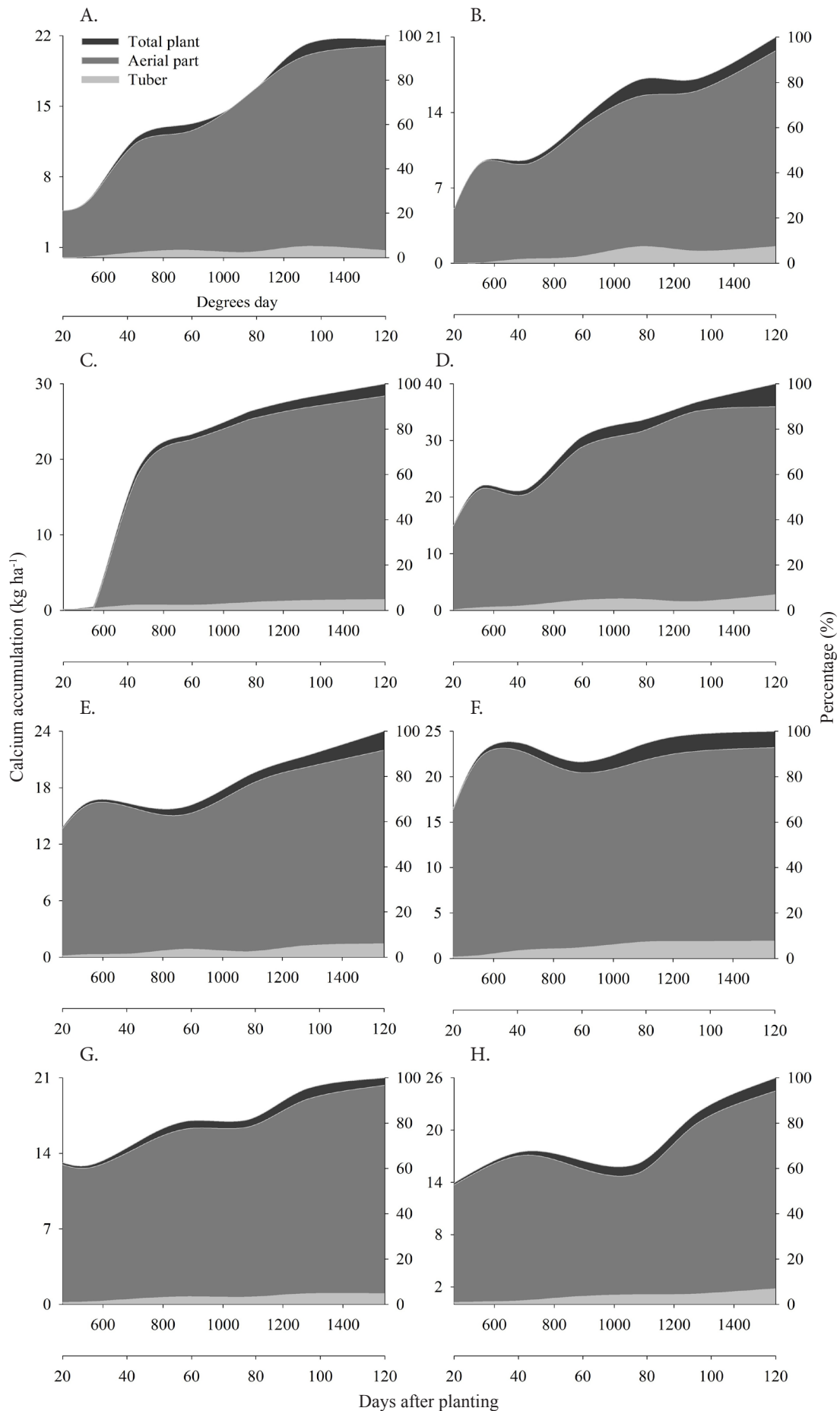


Figure 6. Calcium accumulation in the tubers and in the aerial part during the cycle of the varieties Ágata under low (A) and high fertilization (B), Asterix under low (C) and high fertilization (D), Atlantic under low (E) and high fertilization (F), Taurus under low (G) and high fertilization (H)

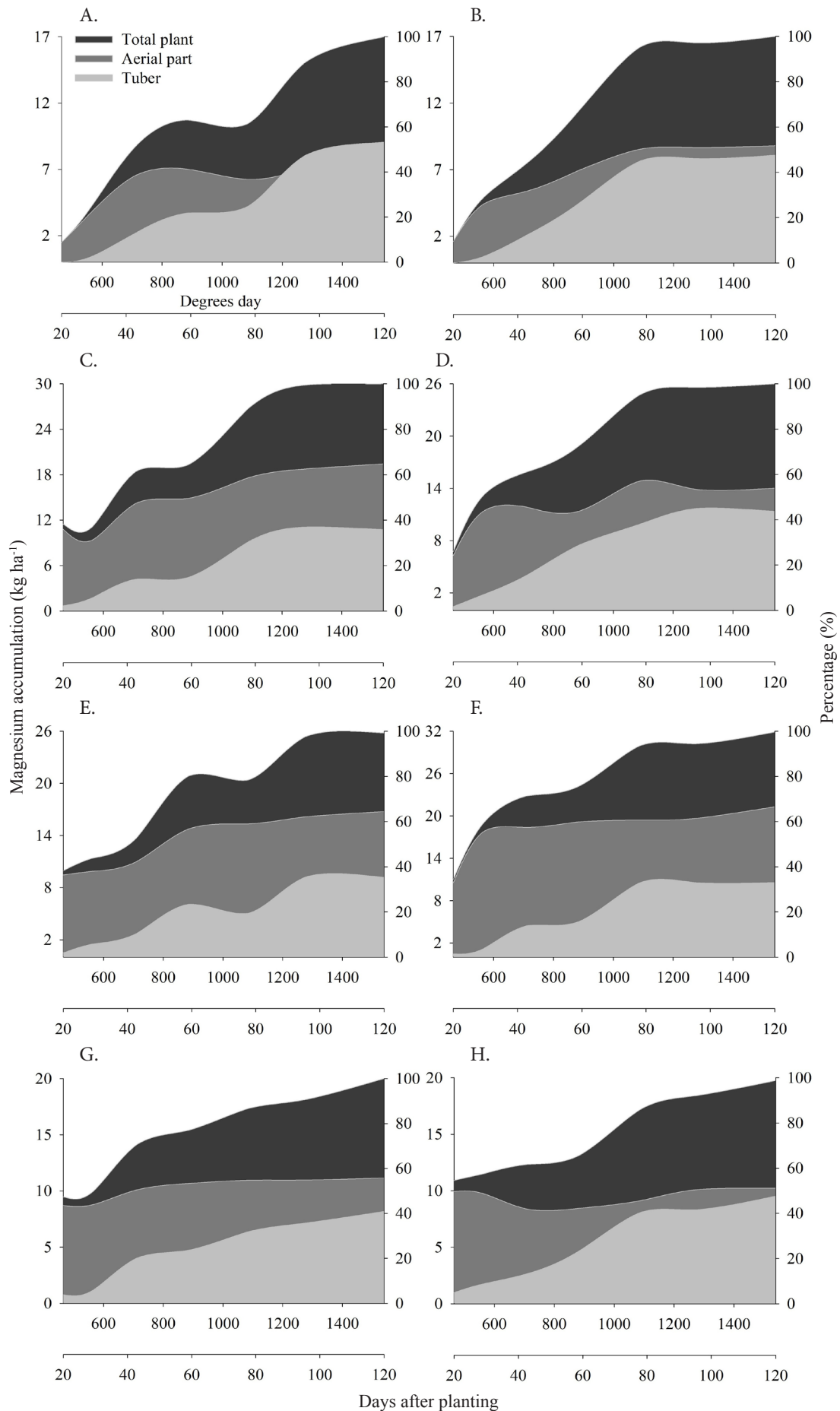


Figure 7. Magnesium accumulation in the tubers and in the shoot during the cycle of the varieties Ágata under low (A) and high fertilization (B), Asterix under low (C) and high fertilization (D), Atlantic under low (E) and high fertilization (F), Taurus under low (G) and high fertilization (H)

responsive to P application, with yields similar to the Ágata variety. Phosphorus responsive Atlantic varieties may not yield to high yields if tuber dry matter partitioning is low (Soratto et al., 2015). These authors attribute this effect to the greater efficiency of some varieties at absorbing P, and to the fact that certain varieties are more productive than others.

The highest accumulated amounts of K were in the Atlantic variety, with low fertilization 13 kg ha⁻¹ in the aerial part, 173 kg ha⁻¹ in the tuberculos and 186 kg ha⁻¹ in total, and in high fertilization 34 kg ha⁻¹ in the aerial part. 231 kg ha⁻¹ in tuberculos and 265 kg ha⁻¹ in total (Figure 5).

The variety Atlantic accumulated 40 and 52 kg ha⁻¹ of K in the aerial part, and 173 and 210 kg ha⁻¹ in the tubers, under low and high fertilization conditions, respectively. The variety Ágata accumulated the least quantity of K, with 162 and 188 kg ha⁻¹ at high and low fertilization conditions, respectively.

Potassium is the most highly accumulated nutrient in potatoes (Nunes et al., 2006). Fernandes et al. (2011) found an average accumulation of 243 kg ha⁻¹ in Mondial and Asterix varieties and 178 kg ha⁻¹ in Ágata, Atlantic and Markies varieties, values close to those found in the present study. This reinforces the need to carry out fertilization recommendations based on specific varieties, since there is a difference in the accumulation of nutrients for each one, especially for N and K. Tailoring potassium fertilization recommendations thus has positive effects on productivity. In addition, the region in which cultivation is taking place should also be considered, and this is why this study was carried out in the Triângulo Mineiro region of Alto Paranaíba, which is the main producer of potatoes in Brazil.

The Asterix variety presented the highest calcium accumulation at low fertilization, 28.4 kg ha⁻¹ in the aerial part, and 1.5 kg ha⁻¹ in the tubers (Figure 6). Under high fertilization, the Asterix variety also presented greater accumulation of this nutrient, of 37 and 2.7 kg ha⁻¹ in the aerial part and in the tubers, respectively. The Ca partition for the shoot was 95% at low fertilization and 93.2% at high fertilization.

Higher calcium accumulation in the aerial part of the potato was also observed by other authors (Cabalceta et al., 2005; Fernandes et al., 2011). This result emphasizes the importance of having good Ca availability in the periods of tubing and tuber filling, because the tuber is less favored in nutrient partitioning in the plant.

The greater accumulation of Ca in the aerial part of the potato than in the tuber is because the translocation of Ca occurs along with the water, being affected by the rate of transpiration. In this way, organs that have higher rates of transpiration receive higher amounts of Ca (Prado, 2008). The tuber presents low transpiration, therefore, the amount of calcium that is directed to this organ is low (Fernandes et al., 2011).

The Asterix variety presented higher magnesium accumulation with low fertilization, while Atlantic variety with high fertilization; the Ágata variety presented lower magnesium accumulation with low high fertilization (Figure 7).

It was found that during the initial development of the crop, up to 45 DAP, magnesium accumulates in greater amounts in the aerial part of the plant, but once tuberization and tuber filling start, the majority of the nutrient is directed to the development and growth of this organ. Among the macronutrients,

magnesium and sulfur are absorbed in smaller quantities by the potato crop (Paula et al., 1986), but deficiency in either of these nutrients compromises the development of the crop, hence their presence in adequate doses remains important.

The Asterix and Atlantic varieties responded significantly by SNK test to fertilizer doses. At high fertilization, the yield of the Asterix variety was 61.4 t ha⁻¹ and at low fertilization 48.6 t ha⁻¹, a difference of 12.80 t ha⁻¹, and the Atlantic variety at high fertilization showed a yield of 53.6 t ha⁻¹ and at low fertilization 45.4 t ha⁻¹, a difference of 8.2 t ha⁻¹. The Taurus and Ágata varieties did not respond to an increase in fertilization doses. The Taurus variety at high fertilization presented a yield of 38.6 t ha⁻¹ and at low fertilization 38.3 t ha⁻¹; the Ágata variety at high fertilization presented a yield of 42.1 t ha⁻¹ and at low fertilization 35.7 t ha⁻¹. This information is useful because it allows a better selection of varieties, an essential step in crop planning and, therefore, a better result of the use of nutrients.

CONCLUSIONS

1. Asterix and Atlantic varieties presented higher N, P and K extraction and, consequently, higher productivity, while Taurus and Ágata varieties extracted smaller amounts of nutrients and presented lower yields.

2. The period of greatest demand for macronutrients for the studied varieties occurs during the tuberization and filling of tubers.

3. The variation between potato varieties in macronutrient extraction indicates a need for differential management in fertilization.

LITERATURE CITED

- Alvares, C. A.; Stape, J. L.; Sentelhas, P. C.; Gonçalves, J. L. M. Sparovek, G. Koppen's climate classification map for Brasil. *Meteorologische Zeitschrift*, v.22, p.711-728, 2013. <https://doi.org/10.1127/0941-2948/2013/0507>
- Aquino, R. F. B. A.; Assunção, N. S.; Aquino, L. A.; Aquino, P. M.; Oliveira, G. A.; Carvalho, A. M. X. de. Nutrient demand by the carrot crop is influenced by the cultivar. *Revista Brasileira de Ciência do Solo*, v.39, p.541-552, 2015. <https://doi.org/10.1590/01000683rbcs20140591>
- Cabalceta, G.; Saldias, M.; Alvarado, A. Absorción de nutrientes en el cultivar de papa MNF-80. *Agronomía Costarricense*, v.29, p.107-123, 2005.
- Cardoso, A. D.; Alvarenga, M. A. R.; Melo, T. L.; Viana, A. E. S. Produtividade e qualidade de tubérculos de batata em função de doses e parcelamentos de nitrogênio e potássio. *Ciência e Agrotecnologia*, v.31, p.1729-1736, 2007. <https://doi.org/10.1590/S1413-70542007000600019>
- Fernandes, A. M.; Soratto, R. P.; Silva, B. L. Extração e exportação de nutrientes em cultivares de batata: I - Macronutrientes. *Revista Brasileira de Ciência do Solo*, v.35, p.2039-2056, 2011. <https://doi.org/10.1590/S0100-06832011000600020>
- Fernandes, A. M.; Soratto, R. P.; Silva, B. L.; Souza-Schlick, G. D. Crescimento, acúmulo e distribuição de matéria seca em cultivares de batata na safra de inverno. *Revista Brasileira de Pesquisa Agropecuária*, v.45, p.826-835, 2010. <https://doi.org/10.1590/S0100-204X2010000800008>

- Mendoza-Cortez, J. W.; Cecílio Filho, A. B.; Rosa, M. O.; Nascimento, C. S. Growth of potato plants of the 'Asterix' cultivar and accumulation of nutrients. *Journal of Agricultural Science*, v.5, p.217-226, 2013. <https://doi.org/10.5539/jas.v5n7p217>
- Miyazawa, M.; Pavan, M. A.; Muraoka, T.; Carmo, C. A. F. S. do; Melo, W. J. de. Análise química de tecido vegetal. In: Silva, F. C. (ed). *Manual de análises químicas de solos, plantas e fertilizantes*. 2.ed. Brasília. Embrapa Informação Tecnológica, 2009. p.191-233.
- Moreira, M. A.; Vidigal, S. M.; Sedyama, M. A. N.; Santos, M. R. dos. Crescimento e produção de repolho em função de doses de nitrogênio. *Horticultura Brasileira*, v.29, p.117-121, 2011. <https://doi.org/10.1590/S0102-05362011000100020>
- Nava, G.; Dechen, A. R.; Iuchi, V. L. Produção de tubérculos de batata-semente em função das adubações nitrogenada, fosfatada e potássica. *Horticultura Brasileira*, v.25, p.365-370, 2007. <https://doi.org/10.1590/S0102-05362007000300009>
- Nunes, J. C. S.; Fontes, P. C. R.; Araújo, E. F.; Sedyama, C. Potato plant growth and macronutrient uptake as affected by soil tillage and irrigation systems. *Pesquisa Agropecuária Brasileira*, v.41, p.1787-1792, 2006. <https://doi.org/10.1590/S0100-204X2006001200014>
- Paula, F. L. M.; Streck, N. A.; Heldwein, A. B.; Bisogni, D. A.; Paula, A. L.; Dellai, J. Soma térmica de algumas fases do ciclo de desenvolvimento da batata (*Solanum tuberosum* L.). *Ciência Rural*, v.35, p.1034-1042, 2005. <https://doi.org/10.1590/S0103-84782005000500008>
- Paula, M. B.; Fontes, P. C. R.; Nogueira, F. D. Produção de matéria seca e absorção de macronutrientes por cultivares de batata. *Horticultura Brasileira*, v.4, p.10-16, 1986.
- Prado, R. M. Nutrição de plantas. 1ed. Jaboticabal: UNESP, 2008. 407p.
- Renato, N. dos S.; Silva, J. B. L.; Sedyama, C.; Pereira, E. G. Influência dos métodos para cálculo de graus-dia em condições de aumento de temperatura para as culturas de milho e feijão. *Revista Brasileira de Meteorologia*, v.28, p.382-388, 2013. <https://doi.org/10.1590/S0102-77862013000400004>
- Ribeiro, A. C.; Guimarães, P. T. G.; Alvarez V., V. A. H. Recomendação para uso de corretivos e fertilizantes em Mina Gerais: 5º aproximação. Viçosa: UFV, 1999. 359p.
- Soratto, R. P.; Pilon, C.; Fernandes, A. M.; Moreno, L. A. Phosphorus uptake, use efficiency, and response of potato cultivars to phosphorus doses. *Potato Research*, v.58, p.121-134, 2015. <https://doi.org/10.1007/s11540-015-9290-8>