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# Potassium uptake kinetics in native forage grass species from Pampa Biome

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**ABSTRACT**: *This study quantified K uptake kinetic parameters in grass species Paspalum notatum, Paspalum urvillei and Axonopus affinis to associate them with growth. Ten milliliters (10 ml) of nutrient solution were collected in two-liter pots - with five repetitions in 24 hours - in order to determine K concentrations in the samples. Shoot and root dry matter, root length, volume, diameter and surface area, as well as kinetic parameters associated with nutrient uptake ($V_{max}$, $K_m$, $C_{min}$ and I) were determined. Species P. notatum was the one presenting the highest root, shoot and total dry matter production, as well as the highest root volume. P. urvillei recorded the highest K content, which may be associated with thinner roots and greater root surface area. A. affinis recorded the highest $V_{max}$ value, which led to greater K uptake efficiency.*
**Key words**: *Paspalum, Axonopus, kinetic parameters, nutrient uptake, maximum inflow.*

# Cinética de absorção de potássio em espécies de gramíneas forrageiras nativas do bioma Pampa

**RESUMO**: *O estudo quantificou os parâmetros cinéticos de captação de K nas gramíneas Paspalum notatum, Paspalum urvillei e Axonopus affinis associados com o crescimento. Dez mililitros (10 ml) de solução nutritiva foram coletados em vasos de dois litros - com cinco repetições em 24 horas - para determinação das concentrações de K nas amostras. A matéria seca da parte aérea e raízes; comprimento, volume, diâmetro e área superficial radicular, bem como parâmetros cinéticos associados à absorção de nutrientes ($V_{max}$, $K_m$, $C_{min}$ e I) foram avaliados. A espécie P. notatum apresentou a maior produção de raiz, parte aérea e MS total, bem como o maior volume de raiz. P. urvillei apresentou o maior teor de K, que pode ser associado a raízes mais finas e resultando em maior área superficial. A. affinis registrou o maior valor de $V_{max}$, o que levou a uma maior eficiência de absorção de K.*
**Palavras-chave**: *Paspalum, Axonopus, parâmetros cinéticos, absorção de nutrientes, influxo máximo.*

The Pampa Biome covers approximately 62% of Rio Grande do Sul (RS) State's territory (PALLARÉS et al. 2005) and it is represented mainly by grass and herbaceous plants belonging to other families, feature that favors the livestock activity. *Axonopus* and *Paspalum* stand out among the most abundant genera of $C_4$ grasses grown in pastures and comprise a large number of species. Despite the widespread use of these grass genera in Brazil both in natural pastures and in breeding processes, their morphological and kinetic parameters associated with nutrient uptake efficiency, which determines their forage production capacity.

In addition to morphological attributes, nutrient uptake efficiency is influenced by nutrient uptake kinetic parameters represented by the maximum uptake rate ($V_{max}$) and by carriers' affinity to the ion to be transported (Michaelis-Menten constant, $K_m$) and by the minimum concentration of nutrients at which the influx of nutrients stops

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happening ($C_{min}$). The interaction between these parameters is used to estimate the nutrient inflow kinetic rate (MARQUES et al., 2020b). Genotypes or species presenting higher $V_{max}$, as well as low $K_m$ and $C_{min}$ values, should uptake more nutrients and be more efficient than others. Although, this response may be different depending on the condition, because a genotype can be more efficient with low nutrient availability, while not so much with high nutrient availability, as this depends on the transport system being expressed. Thus, native grass species can present different features associated with efficient uptake and use of nutrients such as potassium (K), a nutrient with low availability in natural grasslands (MARQUES et al. 2020b).

The joint characterization of growth and nutrient uptake patterns in native forage grass genera can help researchers and producers to identify (i) the pasture areas presenting the greatest potential to uptake nutrients and, consequently, to produce forage in the Pampa Biome and (ii) the pasture areas presenting the greatest potential to respond to fertilization. Thus, this study assessed morphological kinetic parameters, as well as K uptake, that are not known in two species of the genus *Paspalum* and one of the genus *Axonopus*, *Paspalum notatum*, *Paspalum urvillei* and *Axonopus affinis*, which are native grass species found in the Pampa Biome.

The experiment was carried out in the greenhouse of the Soil Department of Federal University of Santa Maria (UFSM), Santa Maria (RS). *Paspalum notatum* Flüggé, *Paspalum urvillei* Steudel and *Axonopus affinis* Chase seedlings were replicated in April 2019, based on the methodology described by MARQUES et al. (2020a). Seedlings were removed from the trays and their root system was washed in distilled water before the experiment. Next, seedlings were placed in pots filled with 50% Hoagland's nutrient solution. The experimental units consisted of 2-L plastic pots filled with nutrient solution and two plants fixed on Styrofoam sheets. Each treatment (species) has followed a completely randomized experimental design, with 5 repetitions (15 pots, in total).

The solution in each pot was continuously aerated. After the acclimation period was over for 5 days, the nutrient solution was replaced by 0.01 mol $L^{-1}$ of $CaSO_4$ solution for 5 days in order to deplete nutrient reserves – the solution was renewed every two days. After reserve depletion period was over, the 50% Hoagland's nutrient solution was added again to each pot.

Ten milliliters (10 ml) of nutrient solution were collected every 1 hour, for 24 hours. After the 24-h collection was over, plants were removed from the pots and fractionated into shoot and roots. Roots were stored in freezer (0 ºC) for 55 days, for further analysis. After this period, they were thawed in water and digitalized on EPSON Expression 11000 scanner at 600 dpi resolution in order to have their morphological parameters characterized in the WinRHIZO software. Next, plants' shoot and roots were dried in forced circulation oven at 65 °C until reaching constant weight. The tissue of shoot and roots were ground (1-mm mesh) and subjected to nitro-perchloric digestion. Photometry (Digimed, BM-62, Brazil) was used to determine K concentrations.

Dry matter and K concentration in plants were used to calculate the following indices: K uptake efficiency (KUE) = (total K concentration in plants) / (root dry matter) and K use efficiency (KUsE)= (total dry matter)$^2$ / (total K concentration in plants). Data on kinetic parameters ($V_{max}$ and $K_m$) were calculated in the Influx software based on the K concentrations observed in the Hoagland's nutrient solution. The $C_{min}$ value was calculated based on nutrient concentrations after 24 hours. The inflow rate (I) was calculated according to CLAASSEN & BARBER (1974). Variables were compared to each other through Tukey test, at 5% probability level. In addition, the principal component analysis (PCA) was applied to native grass species, based on all variables.

*P. notatum* and *P. Urvillei* have produced 55% and 60% more shoot dry matter (DM) than *A. Affinis* (Table 1). The highest root DM value was observed for *P. notatum*; it was 58% and 79% higher than that of *P. Urvillei* and *A. affinis*, respectively. The higher root/shoot ratio observed for *P. notatum* has indicated that this species has greater potential to grow, as highlighted by OLIVEIRA et al. (2018). Roots are key for water and nutrient uptake processes (BASSIRIRAD, 2000), *P. Urvillei* recorded the longest total root length (RL), which was 35% and 60% longer than that of *A. Affinis* and *P. notatum*, respectively. *P. urvillei* and *P. notatum* recorded increased root surface area (RSA). RSA and RL are the most important morphological traits of the root system (BATISTA et al., 2016), since they enhance the approximation and uptake of nutrients such as K, based on diffusion and interception processes.

*P. notatum*, *P. urvillei* and *A. affinis* shoots recorded K concentrations of 16.9, 20.2 and 19.6 g $kg^{-1}$, respectively. The K concentrations in the roots

Table 1 - Morphological parameters and K concentrations in the organs of *P. notatum*, *P. urvillei* and *A. affinis*.

| Morphological Parameters | *P. notatum* | *P. urvillei* | *A. affinis* |
|---|---|---|---|
| Shoot dry matter (g) | 0.64a[(1)] | 0.57a | 0.26b |
| Root dry matter (g) | 0.48a | 0.20b | 0.10b |
| Total dry matter (g) | 1.13a | 0.78b | 0.36c |
| Root/shoot ratio (g) | 0.79a | 0.36b | 0.40b |
| Root length (cm) | 723.6b | 1105.9a | 441.1c |
| Root surface area ($cm^2$) | 130.9a | 133.7a | 67.5b |
| Mean root diameter (mm) | 0.60a | 0.39c | 0.49b |
| Root volume ($cm^3$) | 1.92a | 1.29b | 0.82c |
| Total K in shoot (g $kg^{-1}$) | 16.9b | 20.2a | 19.6a |
| Total K in roots (g $kg^{-1}$) | 8.4a | 5.9b | 2.6c |
| K uptake efficiency | 13.93c | 30.62b | 45.03a |
| K use efficiency | 0.20a | 0.10b | 0.03c |
| $C_{min}$ (μmol $L^{-1}$) | 2.31a[(1)] | 2.31a | 2.46a |
| $V_{max}$ (μmol $g^{-1}$ $h^{-1}$) | 0.12c | 0.35b | 0.64a |
| $K_m$ (μmol $L^{-1}$) | 6.10a | 3.88a | 6.00a |

[(1)] Means followed by the same letter on the lines did not differ from each other in the Tukey test, at 5% probability level; Ns = non-significant.

of species *P. notatum*, *P. urvillei* and *A. affinis* were 8.4, 5.9 and 2.6 g $kg^{-1}$, respectively. *P. urvillei* and *A. affinis* recorded higher K concentration in shoot. However, for this *P. urvillei* probably uses the strategy of larger root surface area and root length with finest roots. This association helped explaining the higher nutrient uptake and higher K concentration in the leaves (Table 1).

Conversely, due to the shorter surface area and root length, to maintain the same K concentration in the shoot as the *P. urvillei*, *A. affinis*, use another strategy, recorded the highest $V_{max}$ value associated with K uptake (Table 1). It may have happened because this plant has higher concentrations of sites for K-uptake per root unit, a fact that increased its potential to uptake nutrients from the solution (BASSIRIRAD, 2000; BATISTA et al., 2016) (Table 1). $C_{min}$ is less important when there is no limitation in nutrients' arrival to the outer surface of the root system. However, $C_{min}$ has great influence on nutrient uptake in nutrient-poor soils such as natural pasture soils (GRASSEIN et al., 2015).

Thus, we have two strategies for obtaining K, as highlighted by ELANCHEZHIAN et al. (2015). One is the external efficiency, which is associated with a higher K absorption capacity due to the higher growth rate, which results in a larger root system for nutrient absorption. The other is internal efficiency, which is associated with greater affinity of transporters and greater absorption capacity per root unit with the high K transport capacity in cell membranes.

Inflow represents the uptake rate per root unit in the acquisition of a certain amount of nutrients. Thus, the low root inflow of a given species can be compensated by the greater growth and volume of its root system (BASSIRIRAD, 2000), as observed for species *P. notatum*, which recorded the lowest nutrient uptake rate per root unit (Figure 1). The PCA has separated *P. notatum*, *P. urvillei* and *A. affinis* into three groups with different behaviors (Figure 1). The *A. affinis* group has shown that this species recorded the highest $V_{max}$ and $C_{min}$ of K and KUE than the *P. urvillei* group, which showed a positive relationship with RL and K concentration in shoot. *P. notatum* was represented by the positive relationship with the root morphological parameters, such as RSA; RV, which contributed to greater KUsE, enabling greater production of total dry matter (TDM).

In conclusion, larger root surface area and root length with finest roots can maximize K uptake by plants and allow greater concentration of K in the shoot of *P. urvillei*. However; although, one species has low root volume may have a high concentration of K in the shoot by greater affinity of transporters and maximum velocity of nutrients absorption per root unit.

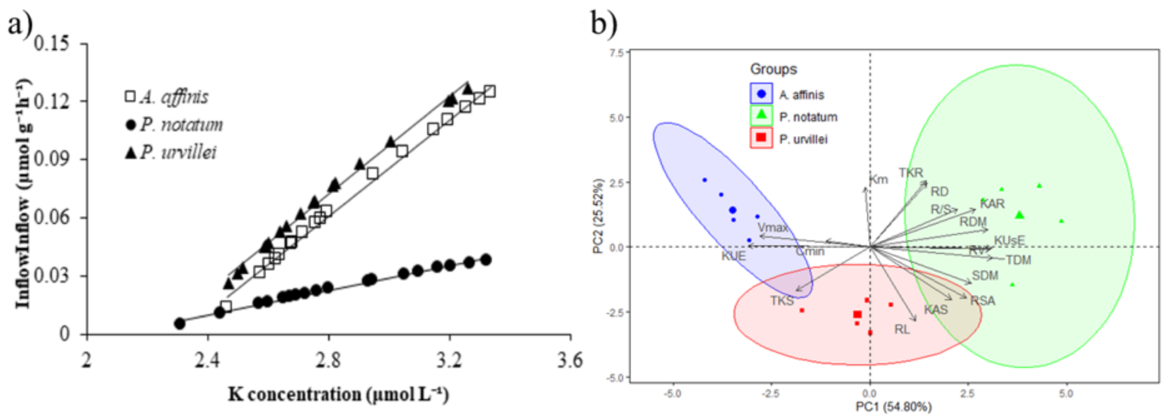


Figure 1 - K inflow rates in *P. notatum*, *P. urvillei* and *A. affinis* (a) and association between principal components 1 (PC1) and 2 (PC2) in K uptake kinetic parameters ($V_{max}$, $K_m$, $C_{min}$), morphological parameters (shoot dry matter – SDM; root dry matter -RDM; total dry matter – TDM; and root/shoot ratio - R/S), nutritional parameters (total K in shoot – TKS; total K in roots – TKR; K accumulated in shoot – KAS; K accumulated in roots – KAR; K uptake efficiency – KUE; K use efficiency – KUsE and root morphological parameters (root surface area - RSA; root volume - RV; mean root diameter – RD; total root length - RL) of *P. notatum*, *P. urvillei* and *A. affinis* (b).

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## DECLARATION OF CONFLICT OF INTEREST

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

## AUTHORS' CONTRIBUTIONS

The authors contributed equally to the manuscript.

## REFERENCES

BASSIRIRAD, H. Kinetics of nutrient uptake by roots: responses to global change. **New Phytologist**, v.147, p.155–169, 2000. Available from: <https://nph.onlinelibrary.wiley.com/doi/10.1046/j.1469-8137.2000.00682.x>. Accessed: Dec. 10, 2019. doi: 10.1046/j.1469-8137.2000.00682.x.

BATISTA, R. et al. Root morphology and nutrient uptake kinetics by Australian cedar clones. **Revista Caatinga**, v.29, p.153–163, 2016. Available from: <http://www.scielo.br/ scielo.php?script=sci_arttext&pid=S1983-21252016000100153>. Accessed: Dec. 6, 2019. doi: 10.1590/1983-21252016v29n118rc.

CLAASSEN, N.; BARBER, S. A. A method for characterizing the relation between nutrient concentration and flux into roots of intact plants. **Plant Physiology**, v.54, p.564-568, 1974.

ELANCHEZHIAN, R. et al. Physiological and molecular approaches for improving phosphorus uptake efficiency of crops. **Current Science**, v.108, p.1271-1279, 2015.

GRASSEIN, F. et al. Relationships between functional traits and inorganic nitrogen acquisition among eight contrasting european grass species. **Annals of Botany**, v.115, p.107–115, 2015. Available from: <https://academic.oup.com/aob/arti-cle/115/1/107/2769200?login=true>. Accessed: Dec. 6, 2019. doi: 10.1093/aob/mcu233.

MARQUES, A. C. R. et al. Interaction between growth strategies and phosphorus use efficiency in grasses from South America natural grasslands. **Revista Ceres**, v.67, p.1-10, 2020a.

MARQUES, A. C. R. et al. Leaf and root attributes as growth and phosphorus uptake determinants in two grass species from South America's natural grasslands. **Journal of Tropical Ecology**, v.36, p.275-281, 2020b. Available from: <https://www.cambridge.org/core/journals/journal-of-tropical-ecology>. Accessed: Dec. 6, 2019. doi: 10.1017/S026646742100002X.

OLIVEIRA, L. B. et al. Phosphorus allocation and phosphatase activity in grasses with different growth rates. **Oecologia**, v.186, p.633–643, 2018. Available from: <https://www.ncbi. nlm.nih.gov/pubmed/29332147>. Accessed: Dec. 6, 2019. doi: 10.1007/s00442-018-4059-9.

PALLARÉS, O. R.; BERRETTA, E. J.; MARASCHIN, G. E. The South American Campos ecosystem. In SUTTIE, J.M.; REYNOLDS, S.G.; BATELLO, C. (eds) **Grasslands of the World**. Rome: FAO, pp.171–219, 2005.