Revista Brasileira de Ciência do Solo

Division - Soil Use and Management | Commission - Soil and Water Management and Conservation

Macronutrient uptake during the plant cycle of pineapple cv. BRS Imperial cultivated in soil with and without plastic mulch cover

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Received: September 25, 2024

Approved: April 10, 2025

How to cite: Borges AL, Coelho EF, Reinhardt DHRC, Lima LWF, Sales MLS, Barros DL, Donato SLR. Macronutrient uptake during the plant cycle of pineapple cv. BRS Imperial cultivated in soil with and without plastic mulch cover. Rev Bras Cienc Solo. 2025;49:e0240197.
https://doi.org/10.36783/18069657rbcs20240197

Editors: José Miguel Reichert and Adelson Paulo de Araújo.

ABSTRACT: Pineapple is a nutrient-demanding plant and information regarding the amounts accumulated in its organs is essential in decision-making for management practices and fertilization recommendations. This study aimed to determine the macronutrient absorption during the plant cycle of pineapple cv. BRS Imperial that was cultivated in sandy loam soil with and without plastic mulch cover. Plants were grown at a spacing of 0.9 × 0.4 × 0.4 m, 38,460 plants per hectare, irrigated by drip and fertilized according to soil analysis, with fertigation on a weekly basis. Experimental design was in randomized blocks, with three replications and treatments arranged in a split-plot scheme, with two soil covers (with and without plastic mulch) in the plots, and five time periods in the subplots (90, 180, 270, 360, and 450 days after planting). Soil cover with plastic mulch promoted higher leaf, stem, and root dry mass in pineapple cv. BRS Imperial throughout the plant cycle. Mulch soil cover determined higher accumulation of all macronutrients in the decreasing order of K, N, Ca, P and Mg. Potassium was the most accumulated in the leaves, whereas N in the stem and roots. Potassium showed higher accumulation rates until 270 days and lower ones up to 450 days after planting; the other macronutrients increased the rates from 270 days after planting. Both dry mass and macronutrient accumulation were much higher in the leaves than in the stem and the roots throughout the plant cycle. Plastic soil cover increases dry mass accumulation of pineapple. Plastic soil cover favors the macronutrient uptake of pineapple. Leaves accumulate most of the macronutrients absorbed by pineapple.

Keywords: *Ananas comosus*, mineral nutrition, macronutrient extraction, mulching.

INTRODUCTION

Pineapple (*Ananas comosus*) is one of the most commercially attractive fruits in the world (Baidhe et al., 2021), mainly due to its very pleasant flavor and aroma. Worldwide production in 2021 was led by Costa Rica, followed by Indonesia, the Philippines and Brazil (FAO, 2021). In Brazil, production was concentrated in the Northeast, North, and Southeast regions, responsible for 94 % of the fruits, especially in the states of Pará, Paraíba, Minas Gerais, and Rio de Janeiro (IBGE, 2022).

In most pineapple-producing regions in Brazil, fusariosis, a disease caused by the fungus *Fusarium guttiforme*, is considered the factor of greatest economic losses to pineapple growers (Ventura et al., 2009). As a result, pineapple breeding programs have focused on searching for fusariosis-resistant varieties. The first hybrid with this characteristic, released by Embrapa, was 'BRS Imperial', resulting from the cross between the cultivars Perolela and Smooth Cayenne, producing leaves without spines and having good physicochemical fruit quality (Cabral and Matos, 2005).

Studies on fertilizer doses indicated greater requirements of this cultivar in terms of nutrition and the possibility of increasing fruit mass by increasing the quantities of nutrients supplied throughout the cycle (Oliveira et al., 2015). However, there has been a lack of basic information on the nutrient uptake rate of this cultivar, which is essential to better define the appropriate times and quantities of nutrients for plants throughout the cycle. The knowledge of nutrient uptake over time is necessary when using the fertigation technique, which needs nutrient application frequency and amount at each application. Even under no fertigation, the crop cycle requires knowledge of the uptake over time (Grangeiro et al., 2007).

Recent studies on nutrient uptake have been conducted with the pineapple cultivar cv. 'MD-2', cv. 'BRS Vitoria', and cv. 'Pérola' (Pegoraro et al., 2014; Silva, 2016). These studies show similarities among the cultivars and some important particularities regarding the absorption and translocation of mineral nutrients, emphasizing the need for more detailed studies for cv. BRS Imperial.

In addition to mineral nutrition, other management practices can influence pineapple fruit size and yield (Souza and Reinhardt, 2009). As pineapple is cultivated in Brazil in many regions whose climate is characterized by long periods of water scarcity, such as the Cerrado and Caatinga biomes, planting in soil covered with plastic mulch has contributed to increasing water availability and, consequently, the absorption and use of nutrients, with favorable results for the development and production of plants (Souza et al., 2019; Coelho et al., 2024). Similar results have been reported in other countries with different environmental conditions, such as Ethiopia (Kelbore et al., 2024).

Plastic mulch was as effective as organic mulching with *Crotalaria juncea* in the development of MD-2 pineapple, in the study carried out in the state of Vera Cruz, Mexico, by Aguilar Pérez et al. (2021), probably due to the maintenance of optimal conditions for crop growth and weed control. Even though it is not organic mulch, the plastic mulching practice minimizes nutrient losses, and the supply of nutrients to plants will occur through soil-plant-microorganism interactions in which the improved soil structure and soil biological activity facilitate nutrient mobilization and nutrient absorption (Friedel and Ardakan, 2021). Mulch combined with the drip irrigation system has become a common agricultural management technique practiced in the commercial production of vegetables, including fruit crops (Pereira et al., 2021; Souza et al., 2021). According to Filipović et al. (2016), this form of management results in several impacts on the distribution of water and nutrients, consequently affecting their dynamics in the soil. According to these authors, in the soil cover system, nutrients are available for longer periods to be absorbed by crops. Zhang et al. (2012) also observed that using soil cover and improving soil moisture status results in greater mineralization and less leaching of nitrogen. This study aimed to determine the macronutrient uptake along the plant cycle of pineapple cv. BRS Imperial in sandy loam soil, with and without plastic mulch cover.

MATERIALS AND METHODS

The study was carried out in the experimental field of Embrapa Cassava & Fruits in Cruz das Almas, Bahia State, located at latitude 12° 40′ 12″ S, longitude 39° 06′ 07″ W, and altitude of 220 m. Climate is Aw type (hot and subhumid tropical) according to Köppen classification system, with annual rainfall of 1,131 mm, average temperature of 24.5 °C and average relative humidity of 80 % (Guimarães et al., 2016). Soil has a sandy loam texture, and its physical and chemical properties are described in table 1.

Slip-type plantlets of cv. BRS Imperial were planted in November 2017, at a spacing of 0.9 × 0.4 × 0.4 m (38,460 plants per hectare) on 0.20 m high by 0.80 m wide beds. Pineapple fertilization followed the recommendations of Oliveira et al. (2017), based on soil chemical analysis performed before planting.

Floral induction of the plants was carried out in November 2018 using ethephon (c.p. Ethrel) with 2 % urea and calcium hydroxide (7 g 20 L^{-1} of water), using 50 mL of the solution per plant. Crop was irrigated when the monthly rainfall was less than 60 mm, which occurred in 11 of the 19 months from planting to harvest.

Experimental design to evaluate the accumulation of dry mass and macronutrients (N, P, K, Ca, and Mg) was randomized blocks with three replicates, with 50 plants per plot and treatments arranged in split plots, with two soil cover conditions (with and without plastic mulch) in the plots and five evaluation times in the subplots (90, 180, 270, 360 and 450 days after planting). Evaluations were carried out with one plant per plot, at 90-day intervals. Mulch used was made of black plastic, with a thickness of 25 microns (25×10^{-6} m).

At each evaluation time, plants were separated into roots, stem, and leaves, and the plant material was dried in a forced air circulation oven at 65 °C until it reached a constant weight for the determination of root dry mass (RDM), stem dry mass (SDM), and leaf dry mass (LDM) with a precision scale. Whole plant dry mass resulted from the sum of the dry masses of the three plant parts (root, stem, and leaves). After drying, the samples were ground in a Wiley mill, using a 1.0-mm-mesh sieve, and 0.5 g of the ground material was removed to determine the contents of the macronutrients N, P, K, Ca and Mg (Tedesco et al., 1995). Determinations were performed in the extracts, after sulfuric digestion (N) and nitric-perchloric digestion (P, K, Ca and Mg). Nitrogen was determined by the Kjeldahl method, P by colorimetry, and K by flame emission photometry. Calcium and Mg contents were obtained by atomic absorption spectrophotometry. Nutrient accumulation, in each organ, was calculated by multiplying the concentration of the nutrient by the amount of dry mass of the parts at all the respective collection times.

Table 1. Physical and chemical properties of the soil (0.00-0.30 m) in the experimental area at Embrapa Cassava & Fruits, in the municipality of Cruz das Almas, Bahia State, Brazil

Particle size			Porosity			Bulk density	Water retention			
Sand	Silt	Clay	Macro	Micro	Total		0.01 MPa	1.50 MPa	Available water	
g kg^{-1}			%			Mg m^{-3}	cm^3 cm^{-3}			
733	94	173	11.98	19.12	31.10	1.55	0.164	0.113	0.051	
pH(H_2O)	P$^{(1)}$	$K^{+(1)}$	$Ca^{2+(2)}$	$Mg^{2+(2)}$	H+Al	$Na^{+(1)}$	SB	CEC	V	OM$^{(3)}$
	mg dm^{-3}	$cmol_c$ dm^{-3}							%	g kg^{-1}
7.3	16	0.08	1.90	1.08	0	0.22	3.28	3.28	100	14

SB: sum of exchangeable bases (K^++Ca^{2+}+Mg^{2+}+Na^+); CEC: cation exchange capacity (SB+H+Al); V: base saturation; OM: organic matter; $^{(1)}$ Extraction with Mehlich-1; $^{(2)}$ Extraction with 1 mol L^{-1} KCl; $^{(3)}$ Modified Walkley-Black method.

Data of root, stem, leaf, and whole plant dry masses and the quantities of the macronutrients N, K, P, Ca, and Mg at the collection times were subjected to homoscedasticity evaluation based on the Shapiro-Wilk test. Transformation of all growth variables and macronutrients was performed, and the analysis of variance considered the sources of variation as the collection time, soil cover condition, and their interaction. When the F-test ($p<0.05$) was significant ($p<0.05$) for one variation source or their interaction, taking into account the splitting of the sum of square errors of the interaction. T-test for means of soil covering (with and without) was performed, fixing the time after planting. Regression analysis of plant-growth variables or macronutrients as a function of time was performed during their cycle, considering the use or non-use of the soil covering. Statistical analyses were carried out using Sisvar software (Ferreira, 2019). Results of the variance analysis were used to construct the figures for dry mass and macronutrient accumulation as a function of the time elapsed from planting. Results of plant dry mass accumulation (g) and nutrient accumulation (g) as a function of time were used to obtain the dry mass accumulation rate (Equation 1) and macronutrient accumulation rate (Equation 2). Nutrient accumulation rate on a specific day after planting was also obtained by the derivative of the fitted functions of the nutrient with time.

$$M's = \frac{M_{j+1}\text{-}M_j}{t_{j+1}\text{-}t_j} \qquad \text{Eq. 1}$$

in which: M’s is the dry mass increment rate between times t_j and T_{j+1}; M_{j+1} is the dry mass accumulated at times t_{j+1} and t_j at each 90-day interval.

$$N' = \frac{N_{j+1}\text{-}N_j}{t_{j+1}\text{-}t_j} \qquad \text{Eq. 2}$$

in which: N’ is the macronutrient accumulation rate between times t_j and t_{j+1}; N_{j+1} is the quantity of nutrient accumulated at times t_{j+1} and t_j at each 90-day interval.

RESULTS AND DISCUSSION

Evolution of the vegetative dry mass of plant organs

Variance analysis showed that soil cover and collection time significantly influenced ($p<0.05$) the total accumulated dry mass during the crop cycle (180 to 450 DAP). Despite the effect of interaction between soil cover and time from planting date, the accumulated dry mass of leaves, stems, and roots were not influenced by soil cover during the crop cycle, except at 450 DAP (Table 2 and Figure 1). The order of dry mass accumulation followed the same pattern as obtained by Hanafi and Halimah (2004).

Regardless of the use or not of soil cover, dry mass accumulation followed an exponential behavior for the whole plant and its organs (Figure 1). These results are similar to those obtained by Silva (2016) with pineapple cv. Pérola's increase slower up to 197 days, notably in the stem.

Knowledge of the dry mass accumulation patterns of a crop allows a better understanding of the factors related to mineral nutrition, since the growth rate of the plant influences the absorption of nutrients (Barbosa et al., 2003). Whole plant dry mass accumulation in pineapple cv. BRS Imperial had the greatest participation of leaves, ranging from 64 to 84 % with the highest proportion at 90 days, followed by the stem (20 %) and roots (10 %) (Table 2).

Table 2. Dry mass of the organs of the pineapple cv. BRS Imperial, grown without and with plastic mulch, throughout the vegetative cycle in the municipality of Cruz das Almas, Bahia State, Brazil, 2018

Organs	Soil cover	Coefficient	Variation time (days)				
			90	180	270	360	450
		%	g per plant				
Leaves	With	14.6	49.44	149.76	156.80	259.80	359.45 a
	Without		40.36	90.62	129.69	164.92	227.79 b
Roots	With	22.6	3.92	14.38	17.69	38.37	73.79 a
	Without		2.50	9.41	12.30	28.71	51.07 b
Stem	With	13.0	8.34	28.18	39.88	71.12	132.70 a
	Without		5.34	26.71	37.04	46.68	79.52 b
Total	With	12.1	61.70	192.32	250.54	369.30	593.87 a
	Without		48.21	126.74	181.88	240.33	358.35 b

Means followed by the same letters in the column, each time, for the same organ, did not differ significantly by the F-test ($p<0.05$).

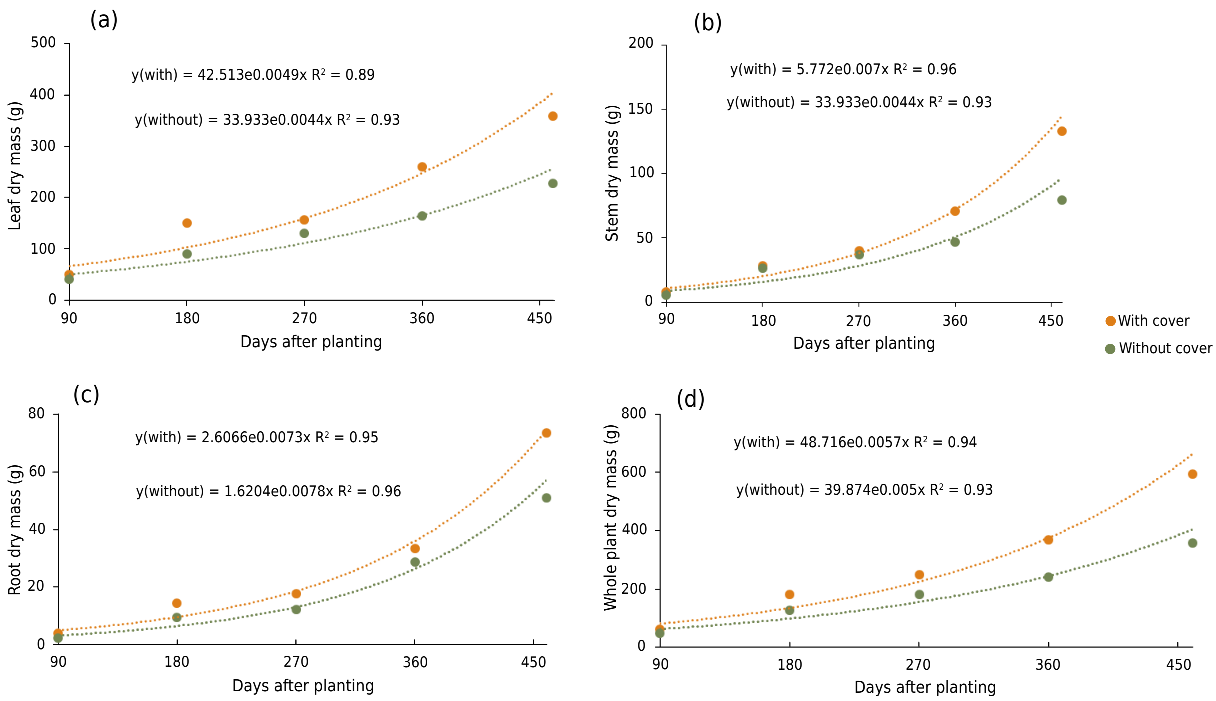

Figure 1. Average dry mass accumulations in the leaves (a), stem (b), roots (c) and whole plant (d) of pineapple cv. BRS Imperial that was grown without cover and covered with plastic mulch, throughout the vegetative cycle in the municipality of Cruz das Almas, Bahia, Brazil, 2018.

The highest dry mass accumulations were observed in plants grown with soil cover, throughout the vegetative cycle, which indicates that soil cover established more favorable conditions for plant development, as it provides better soil moisture and temperature conditions, resulting in greater absorption of water and nutrients by the root system (Patnaik et al., 2022). In 270-360 days, which preceded floral induction, leaf dry mass reached 73 % of its total mass, whereas roots and stem presented about 53 % of its total mass. Oliveira et al. (2015) observed that the dry mass of leaf 'D', a parameter of the vegetative vigor of pineapple, used to define the appropriate time for the application of floral induction, reaches close to 100 % of its development at this stage. According to Malézieux and Bartholomew (2003), regardless of the pineapple cultivar, the greatest gains in dry mass are obtained by the leaves, which results from their ability to maintain photosynthetic capacity for a long period and their lower translocation of photosynthetic products during the vegetative period. The greatest increase in stem mass (61.58 g per plant) was observed in 360-450 days and was higher under soil cover with plastic mulch (Table 2). Roots, in turn, in the same period, reached an increase of 35.42 g per plant (Table 2). The larger dry-mass differences were observed in the stem and roots under soil cover during the interval of 360–450 days after planting (Figure 1). Stem dry mass increased by 61.5 g, and roots, in turn, in the same period, reached an increase of 35.42 g per plant (Table 2).

These results indicate the positive effect of using soil cover on the development of pineapple cv. BRS Imperial. Mulching technique helps retain water and nutrients and minimizes the leaching of nutrients (Kasirajan and Ngouajio, 2012). In addition, it reduces soil temperature fluctuations, the occurrence of plant stress, and the intensity of gas exchange due to stomatal closure, which results in greater biomass accumulation and leaf expansion (Taiz and Zeiger, 2017).

Macronutrient uptake

Analysis of variance showed effects ($p<0.05$) of soil cover and collection time on the amounts of the macronutrients N, P, K, Ca, and Mg absorbed by pineapple cv. BRS Imperial. Soil cover contributed to a greater accumulation of macronutrients when compared with cultivation without soil cover (Table 3).

No statistical differences were observed between the soil cover conditions in the accumulation of macronutrients at 90 days (Table 3). Differences between the soil cover conditions were evident from 180 days for N, K and Ca (Table 3). Accumulation of Mg and P differed significantly between the soil cover conditions from 270 and 360 days onwards, respectively.

Mean differences between the nutrients accumulated in pineapple cv. BRS Imperial under covered and uncovered soil conditions throughout the crop cycle were higher for potassium (2.61 g plant^{-1}), followed by N (1.251 g), Ca (0.46 g), Mg (0.29 g) and P (0.21 g). Mean relative difference was larger for K, except at 90 and 450 days after planting. These differences were determined under the same fertilizer and water (irrigation) application conditions. The use of plastic mulch as soil cover provides milder temperatures and maintenance of adequate moisture for plants, with consequent improvement in environmental conditions for their microbiota (Kasirajan and Ngouajio, 2012; Chen et al., 2020), which may contribute to higher macronutrient extractions (Kasirajan and Ngouajio, 2012). This practice also promotes less cation leaching and N loss by volatilization. These processes improve soil quality, leading to greater availability of nutrients to plants, which translates into higher yields (Zhang et al., 2012).

Table 3. Absorption of macronutrients throughout the cycle of pineapple cv. BRS Imperial, grown without and with soil cover with plastic mulch in the municipality of Cruz das Almas, Bahia, Brazil, 2018

DAP[1]	N		P		K		Ca		Mg	
	With	Without	With	Without	With	Without	With	Without	With	Without
	g per plant									
90	0.69 a	0.47 a	0.10 a	0.07 a	1.50 a	1.09 a	0.28 a	0.14 a	0.18 a	0.09 a
180	2.30 a	1.25 b	0.33 a	0.33 a	4.87 a	1.56 b	0.96 a	0.61 b	0.56 a	0.39 a
270	2.92 a	1.74 b	0.46 a	0.35 a	6.75 a	3.53 b	0.94 a	0.49 b	0.56 a	0.35 b
360	4.54 a	2.62 b	1.09 a	0.83 b	7.53 a	3.94 b	1.62 a	1.03 b	1.15 a	0.77 b
450	7.28 a	5.39 b	2.37 a	1.79 b	9.63 a	7.11 b	2.46 a	1.63 b	1.78 a	1.16 b
CV%	8.2		12.1		14.3		13.6		12.1	

Means followed by the same letters in the row, for each nutrient, did not differ statistically by the F test ($p<0.05$) between the soil cover conditions. [1] DAP: days after planting.

Curves describing the accumulation of the macronutrients N, P, K, Ca and Mg in the plant for the conditions of soil covered with plastic mulch (Figure 2a) and without cover (Figure 2b) show that, in both situations, the most absorbed and accumulated nutrient in the plant was K, followed by N. Potassium accumulation throughout the cycle in the soil with cover was 35 % higher than in the soil without cover, and 4.8 times higher in the soil with cover than the averages recorded for P, Ca and Mg. Nitrogen average accumulation throughout the cycle was 3.6 times higher than the average P, Ca and Mg accumulations.

Except for the accumulation of K with soil cover, which showed logarithmic variation, the others followed an exponential behavior (Figure 2). In cultivation with soil cover, K accumulation rates were higher up to 270 days after planting, decreasing from this point (Figure 2a). Lower accumulation rates were observed up to 270 days for the other macronutrients, with increments from this point onwards. The larger means of K and N accumulation during 90-360 DAP (up to flowering) are in agreement with Pegoraro et al. (2014) and Souza et al. (2019), who studied the Vitoria cultivar. On the other hand, the lower accumulation of these nutrients at 90 DAP in this study agrees with Malézieux and Bartholomew (2003).

In pineapple grown with soil cover (Figure 2a), N accumulation was lower up to 90 days and between 180 and 270 days (below 7.76 mg day^{-1}). At the other times evaluated, it was above 17.0 mg day^{-1}, reaching 30.50 mg day^{-1} between 360 and 450 days. For K, lower accumulations were found up to 90 days and from 270 to 360 days (between 8 and 11 mg day^{-1}) and higher accumulations were found at the other times after 90 days (19.7 to 39.6 mg day^{-1}). Nitrogen is the nutrient that has the greatest effect on pineapple yield (Guarçoni and Ventura, 2011). For P, the accumulation rates were very low, between 1.5 and 7.0 mg day^{-1}, with the highest value (14.0 mg day^{-1}) from 360 to 450 days. For Ca and Mg, the accumulation rates ranged from close to zero to 9.5 mg day^{-1}.

Macronutrient accumulation in pineapple throughout the cycle under cultivation without plastic mulch (Figure 2b) followed the same behavior observed with soil cover at 90-day intervals from planting to the end of the cycle. However, the accumulated values were 34 % lower than those obtained with soil cover for N, K and P. Such differences were 53 % in the case of Ca and Mg.

Considering only the vegetative part of the plant, the greatest accumulation of macronutrients in pineapple cv. BRS Imperial, cultivated with plastic mulch, occurred in the leaves, ranging from 1.14 g of Mg to 5.70 g of K at 450 DAP (Table 4). The order of macronutrient accumulation in the leaves was: K (5.70 g), N (3.49 g), followed by Ca (1.56 g), P (1.15 g) and Mg (1.14 g). This order and the high accumulation values in leaves are well-known in the pineapple literature (Vásquez-Jimenez and Bartholomew, 2018; Souza et al., 2019). In most varieties leaves represent at least 80 % of a vegetative pineapple plant.

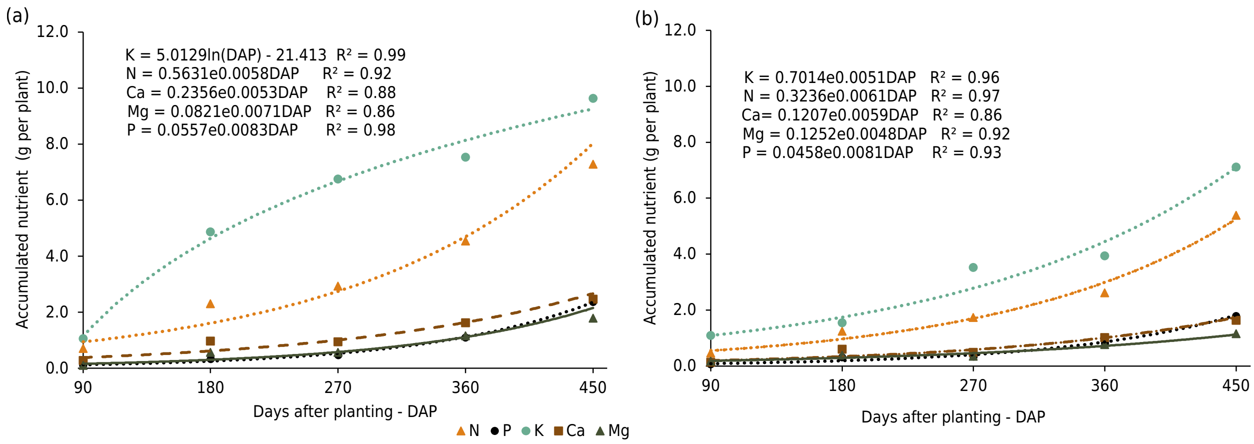

Figure 2. Macronutrient accumulation throughout the cycle of pineapple cv. BRS Imperial, grown with (a) and without (b) soil cover with plastic mulch in the municipality of Cruz das Almas, Bahia, Brazil, 2018.

Table 4. Macronutrient accumulation at 450 days after planting in plant organs of pineapple cv. BRS Imperial that was grown with and without soil cover with plastic mulch in the municipality of Cruz das Almas, Bahia, Brazil

Plant organ	Soil cover	Macronutrient				
		N	P	K	Ca	Mg
		mg per plant				
Leaves	With	3,486 a	1,155 a	5,703 a	1,559 a	1,136 a
	Without	2,206 b	882 b	4,746 b	998 b	696 b
	CV (%)	14.5	36.9	18.2	18.6	
Stem	With	1,270 a	3.1 a	6.7 a	7.5 a	1.2 a
	Without	704 b	2.8 a	4.8 a	6.1 a	1.1 a
	CV (%)	9.13	7.52	20.5	21.4	17.7
Roots	With	744 a	3.1 a	6.6 a	1.2 a	1.2 a
	Without	693 a	2.8 a	4.6 a	1.1 a	1.1 a
	CV (%)	13.3	12.9	16.5	17.9	20.5

Means followed by the same letters in the column, for each nutrient in each organ, did not differ statistically by the F-test ($p<0.05$) between the soil cover conditions.

In the stem, the highest accumulation was observed for N (1,270 mg); for the other macronutrients, the accumulations were much lower, ranging from 1.2 mg (Mg) to 7.5 mg (Ca). The same large differences between N and the other macronutrients studied occurred in the roots. In comparison to the stem, the accumulation in the roots was lower for N and Ca, and similar for P, K, and Mg. The behavior was identical for macronutrient accumulation in plants grown without soil cover but with lower values, with statistical differences for all macronutrients in the leaves and just for N in the stem (Table 4). The order of macronutrient accumulation in the leaves, per plant, was K, N, Ca, P and Mg.

Nitrogen and K accumulation in the leaves of plants grown with soil cover followed a logarithmic behavior, while P and Ca accumulations showed an exponential behavior, and Mg accumulation was linear with time (Figure 3a). Potassium had the highest accumulation rate (30.8 mg day^{-1}) compared to the other nutrients at 90 DAP, with an average reduction rate of 9.8 mg day^{-1} until 450 days.

The same behavior was observed for N, but with accumulation rates of 19.7 mg day^{-1} at 90 DAP and with an average rate reduction of 6.3 mg day^{-1} up to 180 days and 3.8 mg day^{-1} between 360 and 450 days. Phosphosrus accumulation rates ranged from 0.9 mg day^{-1} at 90 days to 8.6 mg day^{-1} at 360 days with an average rate of 4.9 mg day^{-1}. Magnesium accumulation rates did not change during the crop cycle. Calcium accumulation rates ranged from 1.4 mg day^{-1} at 90 days to 7.7 mg day^{-1} at 450 days with an average rate of 3.9 mg day^{-1} during this period (Figure 3a). For plants cultivated without plastic mulch, the accumulation of macronutrients in the leaves showed an exponential behavior, with N and K having higher accumulation rates up to 180 days of 9.74 mg day^{-1} for N and 15.4 mg day^{-1} for K. From 180 days onwards, there were reductions of 7.7 and 6.0 mg day^{-1} for K and 4.8 and 3.8 mg day^{-1} for N. The other nutrients showed low accumulation rates up to 270 days (less than or equal to 1.0 g day^{-1}). From 270 days onwards, there was an increase in accumulation rates with higher values for P (Figure 3b).

In the stem of pineapple cv. BRS Imperial, cultivated in soil with plastic mulch, N was the most accumulated nutrient (Table 4), and its accumulation rate up to 270 days did not differ between the conditions with and without soil cover (less than 2.9 mg day^{-1}). There were increments of 5.1 mg day^{-1} from 270 to 360 days and 9.8 mg day^{-1} from 360 to 450 days in soil with cover, whereas the rates in soil without cover were lower from 270 days onwards (Figure 4).

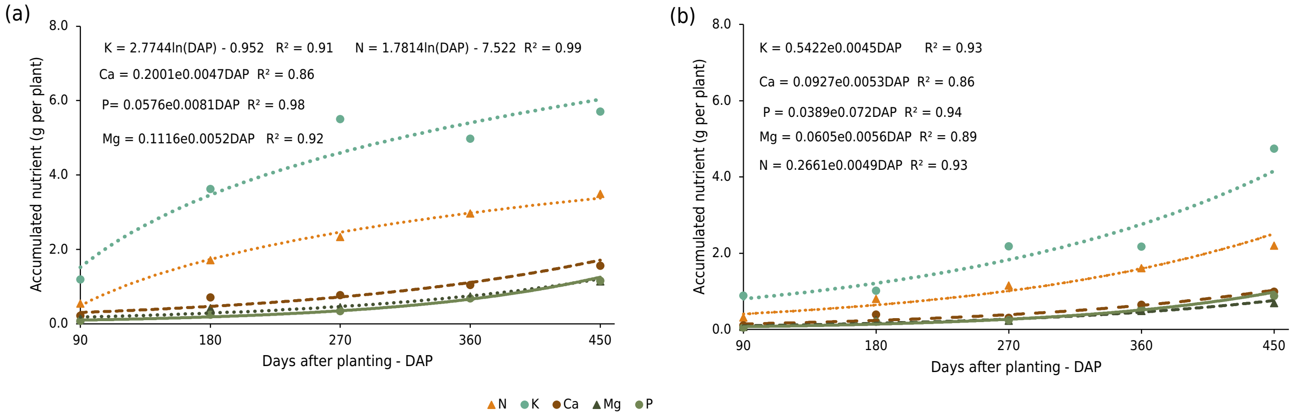

Figure 3. Nitrogen, P, K, Ca, and Mg accumulated in the leaves throughout the cycle of pineapple cv. BRS Imperial, with (a) and without (b) soil cover with plastic mulch in the municipality of Cruz das Almas, Bahia, Brazil.

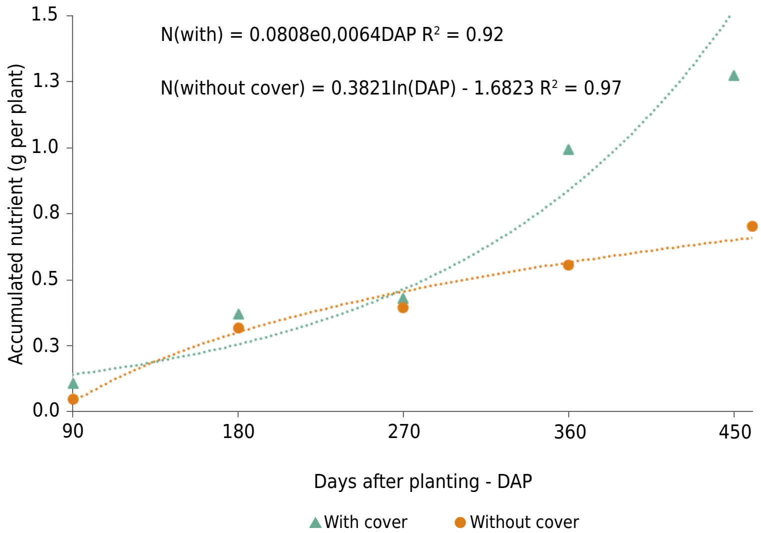

Figure 4. Nitrogen accumulation in the stem of pineapple cv. BRS Imperial that was grown in soil with and without plastic mulch in the municipality of Cruz das Almas, Bahia, Brazil.

Potassium showed increasing accumulation from 180 to 360 DAP with higher values of 3 to 7 mg per plant, and decreased after 360 days (Figure 5a) in the cultivation with plastic mulch. There was no trend of increase in K accumulation along the pineapple cycle, with higher accumulations compared to P and Mg in cultivation without soil cover. Phosphorus accumulations were between 2 and 5 mg in soil covered with plastic mulch and between 1 and 2 mg in soil without plastic mulch. Calcium and Mg did not show, like P, trends in their accumulations. Ca showed higher accumulations (5 to 7 mg per plant) than Mg (0.5 to 1.7 mg per plant) in cultivation with plastic mulch, with no difference compared to the condition without soil cover (Figure 5b).

Concerning the roots, except for N, there was no trend of increase or decrease throughout the cycle in any of the macronutrients, either with or without soil cover with plastic mulch, with accumulations (mg per plant) of 3 to 7 for K, 2 to 4 for P, 7 to 14 for Ca and 0.6 to 2.0 for Mg in cultivation with soil cover (Figure 6a). In pineapple cultivation without soil cover, accumulations varied (mg per plant) from 3 to 8 for K, 1 to 3 for P, 5 to 8 for Ca and 0.5 to 1.0 for Mg (Figure 6b). Nitrogen was the only macronutrient that showed exponential behavior over time for the two cultivation conditions (Figure 6c). with The accumulations up to 270 days were the same for N under conditions of cultivation with and without soil cover, differentiating from then on with values from 30 to 74 mg (with cover) and from 39 to 69 g (without cover).

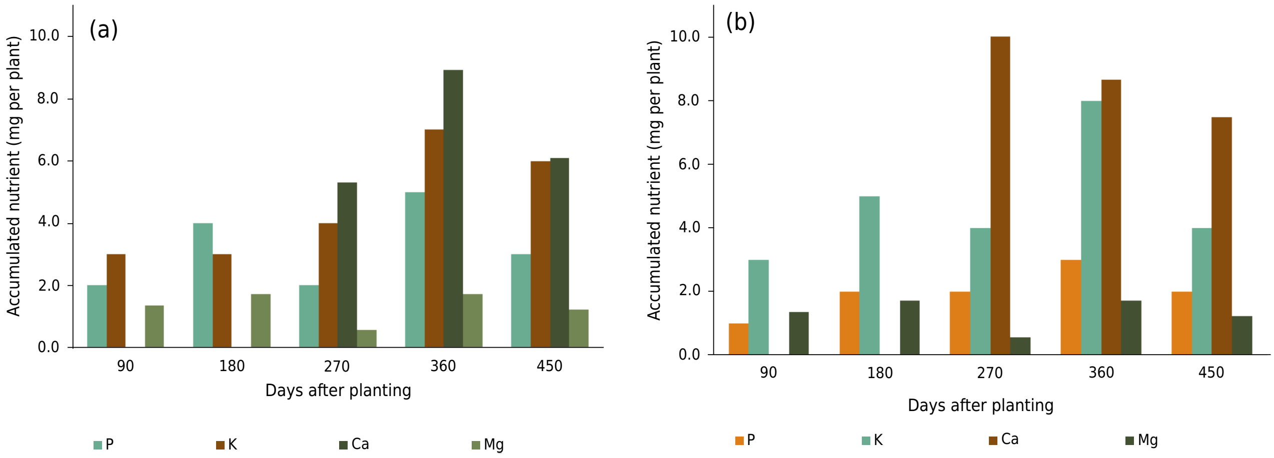

Figure 5. Macronutrient accumulations in the stem of pineapple cv. BRS Imperial that was grown in soil with (a) and without (b) plastic mulch in the municipality of Cruz das Almas, Bahia, Brazil.

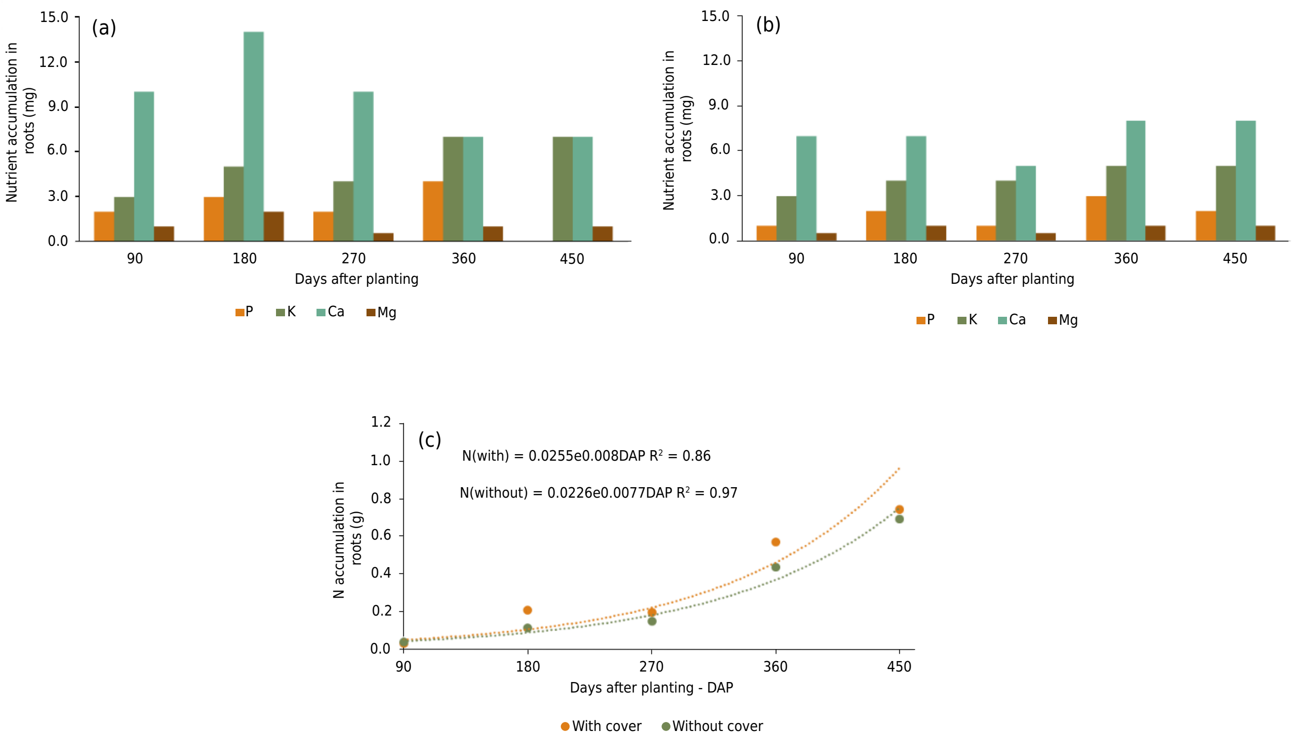

Figure 6. Potassium, K, Ca and Mg accumulations in the roots of pineapple cv. BRS Imperial cultivated with (a) and without (b) soil cover with plastic mulch and N accumulation (c) in the municipality of Cruz das Almas, Bahia, Brazil.

CONCLUSIONS

Soil cover with plastic mulch promoted higher leaf, stem, and root dry mass in pineapple cv. BRS Imperial throughout the plant cycle. Mulch soil cover determined higher accumulation of macronutrients in the decreasing order of K, N, Ca, P and Mg. Potassium was the most accumulated in the leaves, whereas N was in the stem and roots. Potassium showed higher accumulation rates until 270 days and lower ones up to 450 days after planting; the other macronutrients increased the rates from 270 days after planting. Both dry mass and macronutrient accumulation were much higher in leaves than in the stem and roots throughout the plant cycle.

DATA AVAILABILITY

All data was generated or analyzed in this study.

ACKNOWLEDGMENTS

To Embrapa Cassava and Fruits for the technical and physical support of the experiment; to the Graduate Program in Agricultural Engineering/Capes for supporting the doctoral student; and to CNPq (Central National Council for Research and Development) process 310191/2021-1, whose financial support was invaluable in carrying out the research.

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