

## Nutritional demand and nutrient export by modern cultivars of common bean

**Abstract** – The objective of this work was to quantify the extraction and export of nutrients by common bean (*Phaseolus vulgaris*) cultivars from different commercial groups and with different growth habits. The experiment was conducted using four common bean cultivars: TAA Gol, BRS FC104, IPR Tuiuiú, and TAA Dama. Total dry matter (DM) and nutrient accumulation in the V4 (with four, six, and eight three-leaflet leaves), R5, R7, R8, and R9 stages was determined, as well as grain yield and nutrient export. Differences were observed both in nutrient uptake and in DM and nutrient accumulation among the cultivars in the initial stages of development (V4 with six and eight three-leaflet leaves). The TAA Gol cultivar showed a greater accumulation of almost all nutrients in these two initial stages. In R7, the cultivar that had the greatest DM and nutrient accumulation was TAA Dama, but, from R8 onwards, there were no significant differences. Although nutrient export is similar among the evaluated cultivars, a lower percentage is translocated to the grain in TAA Dama.

**Index terms:** *Phaseolus vulgaris*, growth habit, nutrient accumulation, yield.

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## Demanda nutricional e exportação de nutrientes por cultivares modernas de feijão-comum

**Resumo** – O objetivo deste trabalho foi quantificar a extração e a exportação de nutrientes por cultivares de feijão-comum (*Phaseolus vulgaris*) de diferentes grupos comerciais e hábitos de crescimento. O experimento foi conduzido com quatro cultivares de feijão-comum: TAA Gol, BRS FC104, IPR Tuiuiú e TAA Dama. Determinou-se o acúmulo de massa seca (MS) total e de nutrientes nos estádios V4 (com quatro, seis e oito trifólios), R5, R7, R8 e R9, bem como a produtividade de grãos e a exportação de nutrientes por eles. Observaram-se diferenças tanto na absorção de nutrientes como no acúmulo de MS e de nutrientes entre as cultivares, nos estádios iniciais de desenvolvimento (V4 com seis e oito trifólios). A cultivar TAA Gol apresentou maior acúmulo de quase todos os nutrientes nesses dois estádios iniciais. Em R7, a cultivar que obteve maior acúmulo de MS e nutrientes foi TAA Dama, mas, a partir de R8, não houve diferenças significativas. Embora a exportação de nutrientes seja semelhante entre as cultivares, uma menor percentagem é translocada para os grãos em TAA Dama.

**Termos para indexação:** *Phaseolus vulgaris*, hábito de crescimento, acúmulo de nutrientes, produtividade.

## Introduction

Brazil stands out among the largest producers and consumers of common bean (*Phaseolus vulgaris* L.) in the world (FAO, 2019), especially of the carioca and red bean commercial types (Acompanhamento..., 2021). However, starting in the 1970s, there has been a significant change in the commercial types of common bean consumed in the country, with the carioca bean increasingly substituting older commercial types of kidney beans and red beans, among others, which is an indicative that most studies on nutrient uptake are not up to date (Haag et al., 1967; Cobra Netto et al., 1971). For cultivars of the carioca commercial type, for example, few researches on nutritional demand have been conducted.

In addition, more prostrate and late maturing (type III) cultivars have been replaced by more upright and early maturing ones. From the beginning of the decade of 2000 onwards, due to the need for crop mechanization, breeding programs began developing cultivars that matured earlier, were more upright, and showed a more uniform maturity (Melo et al., 2011).

Approximately 160 new cultivars have been registered in the last 15 years, of which 50 were released from 2015 to 2019 and registered in Registro Nacional de Cultivares - RNC (2019). The released cultivars have determinate (type I) and indeterminate (types II and III) growth habits and are of the most diverse commercial groups. A closer analysis shows a considerable concern in releasing new selected and improved materials with an earlier cycle and a higher yield potential than those released previously.

The studies on these new cultivars have aimed to improve the agronomic performance of these materials, focusing on, for example, sowing density and water demand (Soares et al., 2016; Morais et al., 2017). However, there is practically no information on the true nutritional requirements and periods of greater demand for nutrients.

Moreover, most studies on fertilization deal only with nitrogen fertilization, without including requirements for other macro- and micronutrients (Franco et al., 2008; Viana et al., 2011). This creates difficulties for a differentiated fertilization management based on the habit and type of growth of each cultivar.

It is believed that both the uptake curve (extraction) and export of nutrients differ among cultivars. However, there is no known information about very

early and early cultivars with cycles of 60 to 70 days, modern cultivars of black bean commercial types, and cultivars of commercial types with a longer cycle (type III) and a high yield potential.

In fertilization programs in Brazil, made available through recommendation reports, all cultivars, regardless of type (I, II, or III) or commercial group, receive the same amounts of nutrients and are fertilized during the same periods (Sousa & Lobato, 2004). However, cultivars with an early cycle (type I) may have nutritional demands that differ from those with medium and late cycles (types II and III, respectively).

The objective of this work was to quantify the extraction and export of nutrients by common bean cultivars from different commercial groups and with different growth habits.

## Materials and Methods

The experiment was conducted in the mesoregion of Campo das Vertentes, in the municipality of Lavras, in the southern region of the state of Minas Gerais, Brazil (21°20'50"S, 44°98'13"W), in the 2017/2018 crop season. The soil of the site is characterized as a Latossolo Vermelho-Amarelo with a clay texture (Santos et al., 2013), i.e., as an Ustox Oxisol. The soil chemical attributes of the area before soil amendment are shown in Table 1. Accumulated rainfall during November and December 2017 and January and February 2018 was 126, 235, 240, and 85 mm, respectively, and the respective mean monthly temperatures were 21.5, 22.8, 23.0, and 22.7°C.

The experimental design was a randomized complete block with four replicates. Plot area was 28.8 m<sup>2</sup>, with each plot being composed of eight 6.0 m length rows, spaced at 0.6 m. The area of the plot used for data collection were the four center rows, with a 1.0 m border at the extremities of each row, totaling 9.6 m<sup>2</sup>. Of these rows, two were used to collect plants over the crop cycle and two, to estimate grain yield.

Before common bean sowing, 3.0 Mg ha<sup>-1</sup> dolomitic limestone (38% CaO and 12% MgO, with a neutralizing value of 98%, reactivity of 85%, and total neutralizing value of 85%) were applied on soil surface, without incorporation, since the crop was managed under a no-tillage system (Caires, 2013).

Four common bean cultivars with a high yield potential were evaluated: two of type I (TAA Gol and

BRS FC104, from the carioca commercial group), one of type II (IPR Tuiuiú, from the black group), and one of type III (TAA Dama, from the carioca group). On the day of sowing, the seed were treated with the Standak Top (BASF S.A., São Paulo, SP, Brazil) fertilizer, consisting of 25 g L<sup>-1</sup> pyraclostrobin, 225 g L<sup>-1</sup> thiophanate methyl, and 250 g L<sup>-1</sup> fipronil. The sowing densities were 270, 220, and 170 thousand seed per hectare for the type I, II, and III cultivars, respectively. Seed were sown on 11/8/2017, and base fertilization was carried out according to the recommendations of Sousa & Lobato (2004), seeking to achieve a yield of around 60 bags per hectare. Therefore, 26 kg ha<sup>-1</sup> N and 124 kg ha<sup>-1</sup> P<sub>2</sub>O<sub>5</sub> were applied during sowing fertilization, using 325 kg ha<sup>-1</sup> N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O (08-38-00) as a source, which also contained 18% S, 0.45% Zn, 0.45% Mn, 0.15% Cu, and 0.15% B. Soon after sowing, a potassium fertilizer was broadcast using 50 kg ha<sup>-1</sup> K<sub>2</sub>O. Topdressing fertilization was carried out with 90 kg ha<sup>-1</sup> N in the form of urea when the bean plant produced the third three-leaflet leaf (V4 stage).

Weed, disease, and pest control was carried out when necessary, according to monitoring of the area.

**Table 1.** Soil chemical attributes of the Latossolo Vermelho-Amarelo in the experimental area before the experiment was set up.

Attribute <sup>(1)</sup>	Unit	Depth (cm)	
		0-20	20-40
pH water		5.7	5.1
P <sup>(2)</sup>	(mg dm <sup>-3</sup> )	31.2	7.4
K	(mg dm <sup>-3</sup> )	153.0	68.1
Ca	(cmol <sub>c</sub> dm <sup>-3</sup> )	3.0	2.0
Mg	(cmol <sub>c</sub> dm <sup>-3</sup> )	0.8	0.4
Al <sup>3+</sup>	(cmol <sub>c</sub> dm <sup>-3</sup> )	0.0	0.2
H+Al	(cmol <sub>c</sub> dm <sup>-3</sup> )	4.1	4.2
t	(cmol <sub>c</sub> dm <sup>-3</sup> )	4.0	2.0
CEC	(cmol <sub>c</sub> dm <sup>-3</sup> )	8.2	6.4
B	(mg dm <sup>-3</sup> )	0.0	0.0
Cu	(mg dm <sup>-3</sup> )	1.0	3.0
Fe	(mg dm <sup>-3</sup> )	64.0	67.0
Mn	(mg dm <sup>-3</sup> )	12.0	6.6
Zn	(mg dm <sup>-3</sup> )	7.0	2.0
Al saturation (m)	(%)	0.1	6.8
OM	(dag kg <sup>-1</sup> )	2.1	1.6
S	(mg kg <sup>-1</sup> )	0.13	8.2

<sup>(1)</sup>t, effective cation exchange capacity; CEC, cation exchange capacity; and OM, organic matter. <sup>(2)</sup>Obtained by Mehlich-1.

Plants were collected to evaluate nutrient accumulation in the following phenological stages: V4 (four, six, and eight three-leaflet leaves), R5, R7, R8, and R9. The plants were cut at soil level and were separated, according to each stage, into leaves, stems, pods, and grains. In V4, the whole plant was evaluated, without any separation; in R5 and R7, the plants were separated into leaves and stems; in R8, the separate compartments of leaves, stems, and pods (with grain) were evaluated; and, in R9, the plants were separated into leaves, stems, pods, and grain. TAA Gol plants were collected at the eight three-leaflet leaves/R5 stage, since this cultivar is early maturing and some plants already had flower buds at this stage.

Total dry matter and nutrient accumulation were determined in each phenological stage, as well as nutrient export by the grain. For this, plant matter was dried in a laboratory oven at 65°C, ground, and then sent to a laboratory for the determination of N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, and Zn contents, as by described by Silva (2009). Grain yield was determined considering the harvest of two 6.0 m length rows, and grain moisture was standardized at 13%.

Nutrient uptake curves were constructed according to the phenological stage of the crop. Analyses of variance were performed on the experimental data to check for differences in nutrient uptake among the cultivars in each phenological stage. When there was a significant effect, the treatments were compared by the Scott-Knott means clustering test, at 5% probability.

## Results and Discussion

Total dry matter (DM) production in R9 and grain yield did not vary among the evaluated cultivars (Table 2). The mean grain yield was 2,782 kg ha<sup>-1</sup>, and the mean DM was 5,572 kg ha<sup>-1</sup>. The BRS FC104 and TAA Gol type I cultivars, of the carioca group, had a mean DM of 5,096 and 5,679 kg ha<sup>-1</sup>, respectively, whereas IPR Tuiuiú, of the black group, reached 5,884 kg ha<sup>-1</sup>. Although cultivar TAA Dama has an indeterminate growth habit and a greater tendency of vegetative growth compared with type I and II cultivars, it produced 5,708 kg ha<sup>-1</sup>, not differing significantly from the other ones.

DM production was lower at the beginning of the common bean cycle up to R5, representing 14 to 18% of the total, depending on the cultivar (Table 2). At the

beginning of flowering, there was a greater increase in DM, especially for cultivar TAA Dama, being of 49% in R7, when pod production begins. Cultivars with a shorter cycle have a faster initial development than those with a longer cycle because of their lower thermal requirements to reach each phenological stage. This was confirmed by Teixeira et al. (2015), who found that cultivar BRS Radiante (type I) had a faster vegetative development, with an accumulation of 207.3 degree-days from emergence to the V4 stage, compared with Pérola (type III), which required 249.1 degree-days. Cultivars with an indeterminate habit and a longer cycle show a slower increase in total DM at the beginning of the cycle near flowering, reaching a maximum rate of absolute growth closer to flowering (Andrade et al., 2009; Brito et al., 2009).

Gains in dry matter accumulation during grain filling (R8) increased significantly (Table 2), reaching 90% of the accumulated total for the TAA Dama cultivar and around 65% for the other ones, with maximum production at physiological maturity (R9). The greater DM accumulation by TAA Dama was expected because it is a type III cultivar with an indeterminate growth habit and shows an intense vegetative growth, with overlapping of the vegetative and reproductive stages (Nóbrega et al., 2001; Brito et al., 2009).

Leaf and stem DM production increased in all cultivars up to R8. At the beginning of this stage, there was a decline in the DM of those compartments due to the loss of leaves and routing of photoassimilates to younger leaves and the grain, leading to an increase in grain DM until reaching physiological maturity

(Figure 1). This same response was reported by Nascente et al. (2016) for cultivars with a very early cycle, such as IPR Colibri and the CNFC 15873, CNFC 15874, and CNFC 15875 experimental cultivars. Andrade et al. (2009) also observed a decline in the leaf DM of cultivars Ouro Negro and BRS MG Talismã beginning at 51 days after emergence, in the R7 phenological stage.

The grain yield of all cultivars (Table 2) was greater than 2,500 kg ha<sup>-1</sup>, well above the mean yield in Brazil for colored and black beans in the 2018/2019 crop season, which was of 1,400 kg ha<sup>-1</sup> (Acompanhamento..., 2019). The BRS FC104 carioca cultivar has had a satisfactory yield in the southern region of Minas Gerais, even in periods of little rain during its growth cycle, which can be attributed to its more efficient use of the moisture and nutrients available in the soil solution due to its shorter growing period (early cycle). Melo et al. (2011) found that BRS FC104 can complete its cycle in 65 days; however, in the present study, it was of 77 days, showing that the cycle of the cultivar depends on the region it is grown because the local temperature affects the accumulation of degree-days, with direct effects on the plant cycle.

The studied common bean cultivars differed regarding the accumulation of macro- and micronutrients during the vegetative and reproductive phases (Table 3 and Figures 2 and 3). The main differences were observed in the vegetative phase, in the V4 stage, when the plants had six to eight three-leaflet leaves. In general, TAA Gol, which is an earlier cultivar, accumulated more nutrients than TAA Dama and IPR Tuiuiu in this stage of development. However,

**Table 2.** Total dry matter accumulation in the vegetative (four, six, and eight three-leaflet leaves) and reproductive (R5; R7; R8; and R9) phenological stages and grain yield of the TAA Dama, BRS FC104, TAA Gol, and IPR Tuiuiu common bean (*Phaseolus vulgaris*) cultivars<sup>(1)</sup>.

Cultivar	Number of three-leaflet leaves			R5	R7	R8	R9	Yield (kg ha <sup>-1</sup> )
	4	6	8					
	----- kg ha <sup>-1</sup> (%) <sup>(2)</sup> -----							
TAA Dama	405a (7)	504b (9)	795b (14)	1,048a (18)	2,800a (49)	5,113a (90)	5,709a	2,748a
IPR Tuiuiu	500a (8)	541b (9)	769b (13)	823a (14)	1,849b (31)	3,710a (63)	5,885a	2,806a
BRS FC104	527a (10)	391b (8)	600b (12)	859a (17)	1,557b (31)	3,383a (66)	5,097a	3,016a
TAA Gol <sup>(3)</sup>	540a (10)	715a (13)	1,268a (22)	ND	2,098b (37)	3,741a (66)	5,679a	2,549a
CV (%)	18.1	15.0	15.5	15.2	20.0	25.1	10.5	11.9

<sup>(1)</sup>Means followed by equal letters, in the column, do not differ from each other by the Scott-Knott test, at 5% probability. <sup>(2)</sup>Values between parentheses represent the percentage of dry matter accumulated in each phenological stage. <sup>(3)</sup>For cultivar TAA Gol, the eight three-leaflet leaves/R5 stage corresponds to the eight three-leaflet leaves/V4 stage. ND, not determined.

BRS FC104, which is early maturing like TAA Gol (65–70 days), accumulated nutrients the same way that cultivars with a normal cycle do. This shows the importance of knowing the uptake rate of each cultivar to avoid generalizations.

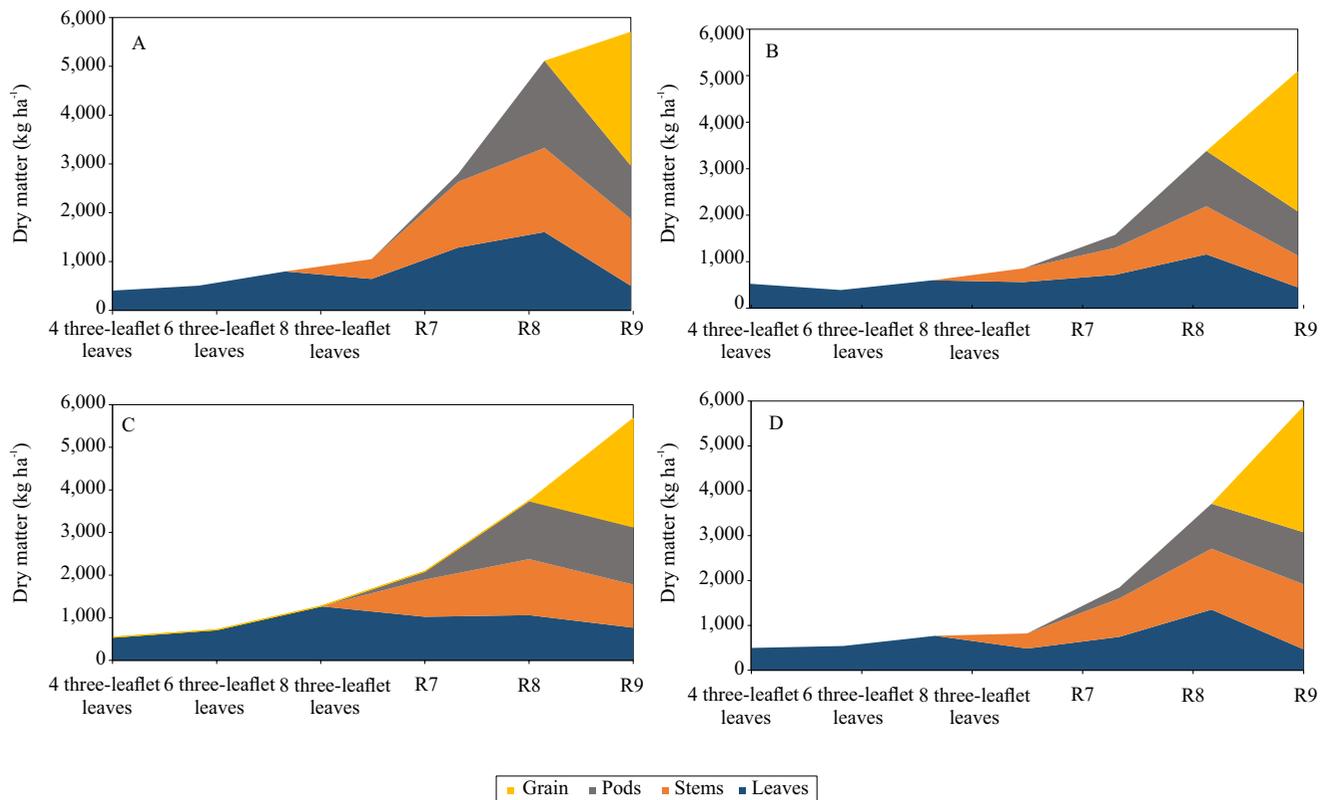
When the TAA Gol cultivar was in the V4 stage with six three-leaflet leaves, it already had a greater DM accumulation than the other ones, including BRS FC104, which has a similar cycle (Table 2). Therefore, especially because of a greater DM accumulation in this phase, that cultivar exhibited the greatest accumulation of all nutrients. Nascente et al. (2016) evaluated nutrient uptake in cultivars with a very early cycle (63 days when sown in the rainy season) and reported a considerable uptake of N, P, and K up to 40 days after emergence, which decreased soon after flowering.

In the R7 stage (pod formation), the cultivar with greatest accumulation of macro- and micronutrients was TAA Dama, also due to a greater DM production in this stage of development (Table 3). Fernandes

et al. (2013) also found a greater accumulation of micronutrients (B, Cu, Fe, Mn, and Zn) during pod formation (R7) in cultivars Pérola and IAC Alvorada, which have an indeterminate type III growth habit like TAA Dama. In previous studies, such as that of Haag et al. (1967), type III cultivars also reached maximum nutrient accumulation near 50 days.

For macronutrients, Vieira et al. (2009) observed differences in the accumulation of S at the end of the cycle, when cultivar Ouro Vermelho (type III) accumulated a greater amount of S (3.43 kg ha<sup>-1</sup>) than the other type I and II cultivars of special groups, such as BRS Radiante and Bolinha. The amounts of S accumulated by these cultivars are significantly lower than those obtained in the present study (mean of 11.1 kg ha<sup>-1</sup>). The DM and grain yields were also much lower (2,328 kg ha<sup>-1</sup> DM and 850 kg ha<sup>-1</sup> grain) than those found here (Table 2).

From grain filling (R8) onwards, there were no differences in nutrient accumulation among the



**Figure 1.** Dry matter accumulation in the phenological stages – four, six, and eight three-leaflet leaves; R5; R7; R8; and R9 – of different compartments (leaves, stems, pods, and grain) of the TAA Dama (A), BRS FC104 (B), TAA Gol (C), and IPR Tuiuiú (D) common bean (*Phaseolus vulgaris*) cultivars.

cultivars (Table 3). At that stage, TAA Dama had already taken up the maximum amount of all nutrients, which decreased after R8 due to losses of lower leaves and to the translocation of nutrients to the grain (Figure 2). The accumulation of nutrients in the leaves also decreased in the other cultivars, showing that, in the grain-filling stage, energy demand is greater in this compartment, requiring the redirection of assimilates (Gallo & Miyasaka, 1961). For all cultivars, except TAA Dama, the P, Mg, and S nutrients were taken up until the end of the cycle. Moreover, there was no difference in the total accumulation of nutrients by plants at physiological maturity (R9).

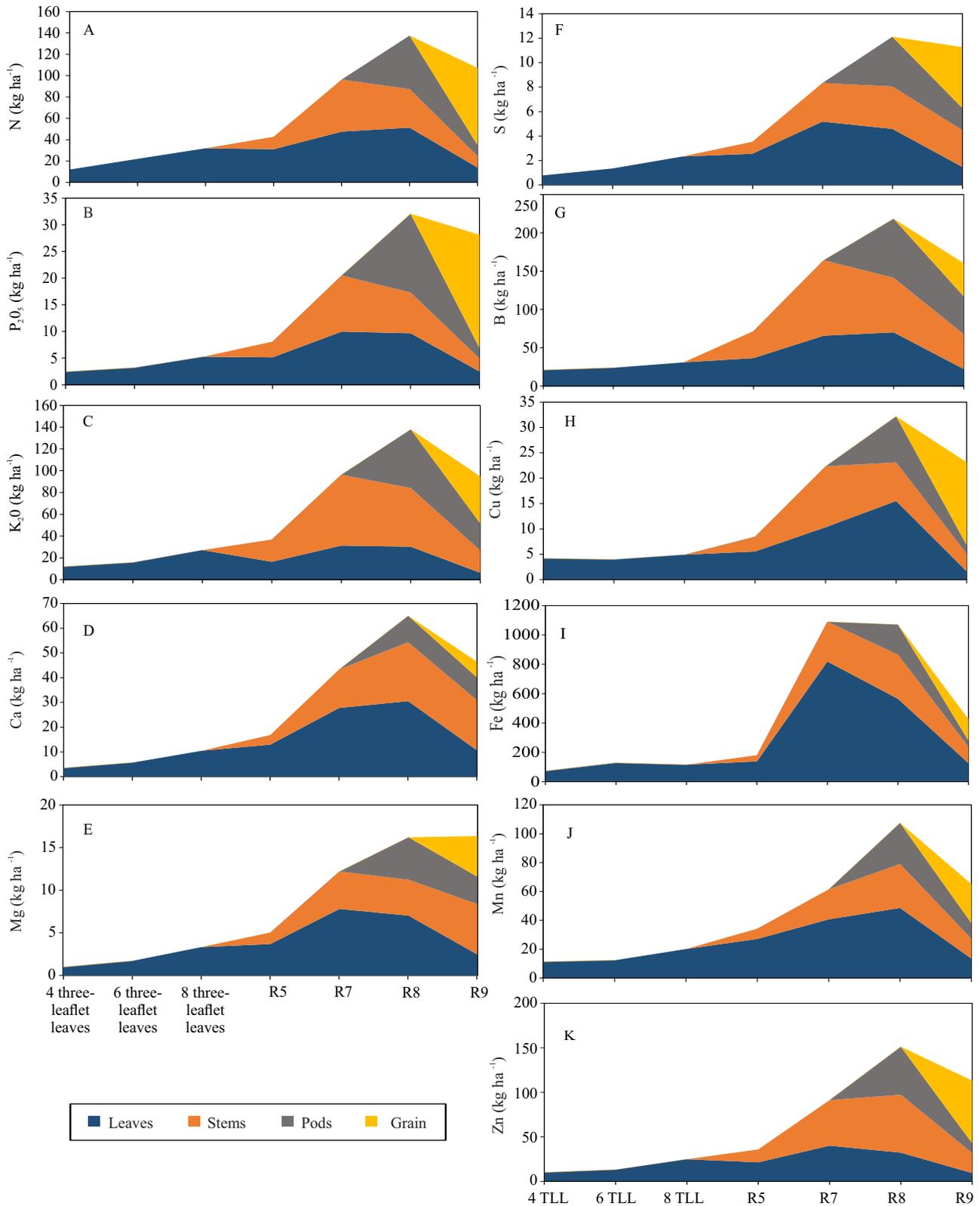
Although the nutrient uptake rate differed among cultivars (Table 3), in general, nutrient export per

hectare or per megagram of grain was similar. The only exceptions were: Ca, which was exported in a greater amount by cultivar IPR Tuiuiu; S, which was exported in a greater amount by BRS FC104; and B, which was exported in a greater amount by BRS FC104 and IPR Tuiuiu (Table 4). Regarding management, this is important information because it shows that the amounts of nutrients applied should not be increased for these cultivars and that the period of greatest nutrient demand can vary, suggesting that the fertilization of some nutrients should be advanced for early maturing cultivars (Nascente et al., 2016). Despite the similarity in the exported amounts, the percentage of exported nutrients in relation to total

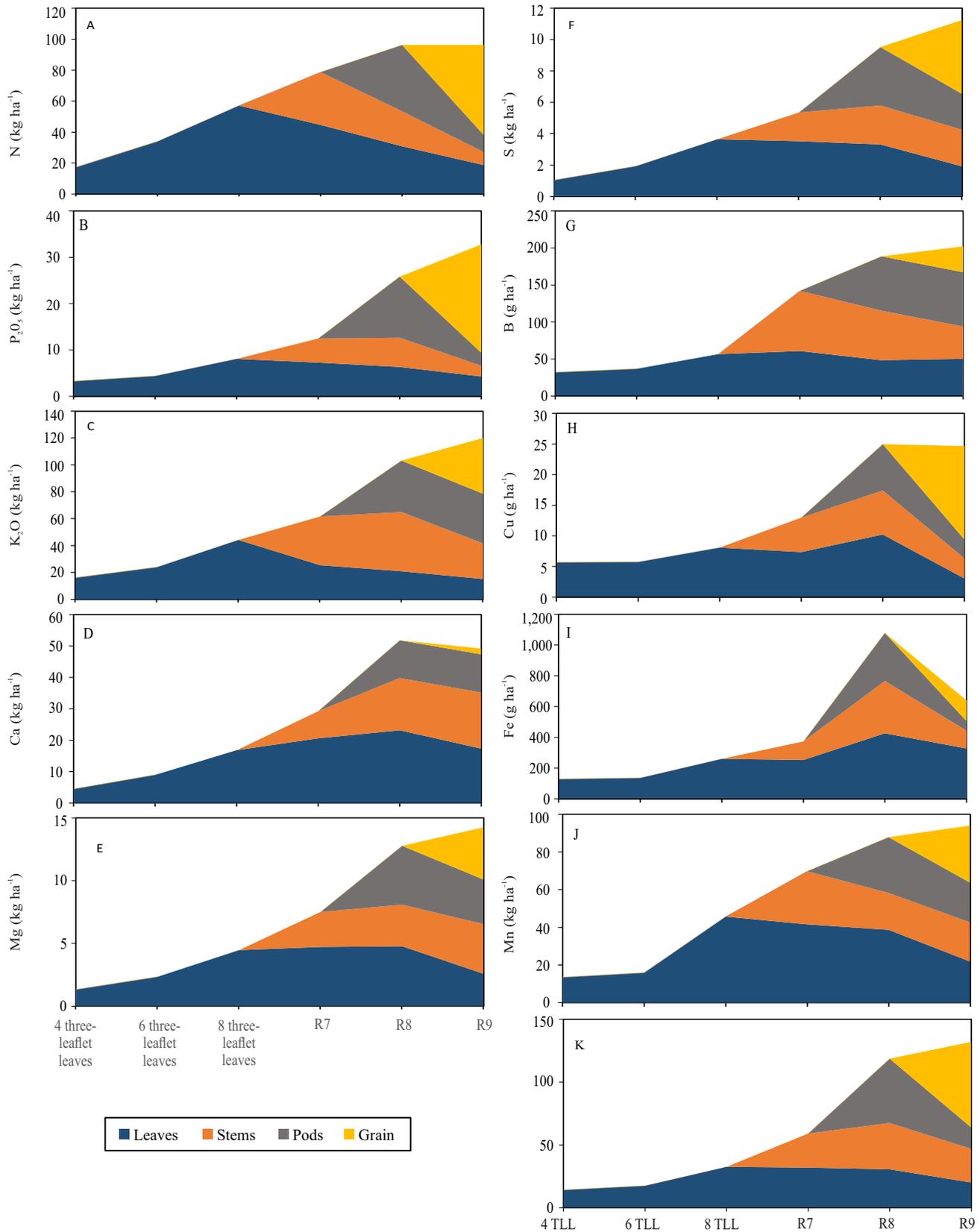
**Table 3.** Nutrient accumulation by the TAA Dama, BRS FC104, TAA Gol, and IPR Tuiuiu common bean (*Phaseolus vulgaris*) cultivars in their vegetative and reproductive phenological stages<sup>(1)</sup>.

Phenological stage	Cultivar	N						S					
		(kg ha <sup>-1</sup> )											
		(kg ha <sup>-1</sup> )						(g ha <sup>-1</sup> )					
		N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	Ca	Mg	S	B	Cu	Fe	Mn	Zn	
4 three-leaflet leaves	TAA Dama	11.9a	2.4a	11.8a	3.4a	1.0a	0.8a	20.9b	4.2a	72.0a	11.2a	9.9b	
	IPR Tuiuiu	13.8a	3.2a	16.2a	4.3a	1.0a	0.9a	26.3b	4.8a	110.8a	17.9a	13.9b	
	BRS FC104	17.7a	3.4a	16.5a	5.1a	1.3a	1.1a	32.0a	5.1a	138.9a	16.7a	14.6a	
	TAA Gol	17.3a	3.3a	16.1a	4.4a	1.3a	1.0a	32.0a	5.7a	128.7a	13.4a	14.3a	
6 three-leaflet leaves	TAA Dama	22.0b	3.2b	15.7a	5.6b	1.7b	1.3b	23.9b	3.9b	127.6b	12.3b	13.1a	
	IPR Tuiuiu	21.1b	3.5b	18.6a	6.3b	1.7b	1.4b	27.5b	3.8b	89.4b	18.3a	18.3a	
	BRS FC104	17.7b	2.3b	12.7a	4.9b	1.3b	1.0b	23.7b	3.0b	58.9b	8.2b	9.1a	
	TAA Gol	34.0a	4.4a	24.0a	9.0a	2.3a	1.9 <sup>a</sup>	36.7a	5.7a	135.9a	15.9a	17.5a	
8 three-leaflet leaves <sup>(2)</sup>	TAA Dama	31.9b	5.3b	27.1b	10.4b	3.3b	2.3b	30.9b	4.9b	115.0b	20.1b	24.9b	
	IPR Tuiuiu	29.1b	4.6b	25.3b	10.1b	2.6b	2.0b	35.0b	5.2b	109.2b	27.6b	20.4b	
	BRS FC104	25.5b	3.7b	21.6b	7.5b	1.9b	1.5b	29.7b	4.0b	90.8b	16.1b	14.9b	
	TAA Gol	57.1a	8.1a	44.3a	16.8a	4.5a	3.6 <sup>a</sup>	56.6a	8.1a	260.3a	45.6a	32.6a	
R5	TAA Dama	42.7a	8.1a	36.9a	16.8a	5.0a	3.5a	71.8a	8.5a	180.0a	34.2a	35.8a	
	IPR Tuiuiu	31.3a	5.7a	29.2a	13.5a	3.2a	2.4a	75.0a	7.5a	165.3a	29.3a	26.6b	
	BRS FC104	38.1a	6.4a	31.9a	12.3a	3.3a	2.7a	78.0a	6.2a	193.0a	24.0a	23.7b	
	TAA Gol	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
R7	TAA Dama	96.3a	20.5a	96.4a	43.4a	12.2a	8.3a	164.3a	22.4a	1089.5a	61.5a	91.2a	
	IPR Tuiuiu	57.4b	12.4b	68.2b	27.2b	6.7b	4.9b	108.0b	14.8b	526.7b	58.0a	55.8b	
	BRS FC104	41.0b	8.3c	43.7c	21.9b	5.3b	3.7b	86.1b	7.8c	172.8b	29.2b	38.4c	
	TAA Gol	78.7a	12.5b	61.5b	29.3b	7.5b	5.4b	142.2b	13.0b	373.9b	69.8a	59.2b	
R8	TAA Dama	137.6a	32.1a	138.0a	65.0a	16.2a	12.1a	218.4a	32.2a	1070.5a	107.5a	151.3a	
	IPR Tuiuiu	94.6a	25.6a	117.7a	51.2a	11.1a	8.8a	172.7a	28.0a	499.5a	99.4a	125.6a	
	BRS FC 104	83.2a	21.1a	94.9a	48.0a	11.9a	8.4a	165.6a	21.8a	873.5a	72.0a	135.8a	
	TAA Gol	96.3a	25.8a	103.1a	51.8a	12.8a	9.5a	188.9a	25.0a	1078.9a	87.9a	118.6a	
R9	TAA Dama	107.2a	28.2a	94.8a	46.4a	16.4a	11.3a	160.4a	23.1a	426.3a	65.2a	113.0a	
	IPR Tuiuiu	89.5a	25.7a	110.6a	48.6a	15.0a	11.1a	177.5a	24.1a	418.8a	82.9a	110.1a	
	BRS FC104	107.9a	29.2a	97.7a	34.9a	13.1a	10.6a	144.5a	19.4a	428.0a	80.9a	118.5a	
	TAA Gol	96.3a	32.8a	119.9a	49.2a	14.3a	11.2a	202.2a	24.7a	641.6a	94.0a	132.0a	

<sup>(1)</sup>Means followed by equal letters, in the column, for each stage, do not differ from each other by the Scott-Knott test, at 5% probability. <sup>(2)</sup>For cultivar TAA Gol, this stage corresponds to eight three-leaflet leaves/R5 stage. ND, not determined.



**Figure 2.** Macro- and micronutrient accumulation in the phenological stages – four, six, and eight three-leaflet (TLL); R5; R7; R8; and R9 – of different compartments (leaves, stems, pods, and grain) the TAA Dama common bean (*Phaseolus vulgaris*) cultivar.



**Figure 3.** Macro- and micronutrient accumulation in the phenological stages – four, six, and eight three-leaflet leaves (TLL); R7; R8; and R9 – of different compartments (leaves, stems, pods, and grain) of the TAA Gol common bean (*Phaseolus vulgaris*) cultivar.

nutrient uptake was generally lower for the TAA Dama type III cultivar.

Fernandes et al. (2013) observed nutrient exports in the order of 89, 26, 549, 313, and 92 g ha<sup>-1</sup> for B, Cu, Fe, Mn, and Zn, respectively, which are amounts greater than those found in the present study. However, Soratto et al. (2013) generally reported exports of macro- and micronutrients by cultivars Pérola and IAC Alvorada (type III) near those obtained in the present work, which were of 27.0, 3.0, 15, 2.0, 2.0, and 1.5 kg ha<sup>-1</sup> for N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O, Ca, Mg, and S, respectively.

**Table 4.** Nutrient exportation by the TAA Dama, BRS FC104, TAA Gol, and IPR Tuiuiú common bean (*Phaseolus vulgaris*) cultivars<sup>(1)</sup>.

Nutrient	Export			
	TAA Dama	BRS FC104	TAA Gol	IPR Tuiuiú
	----- kg ha <sup>-1</sup> (%) <sup>(2)</sup> -----			
N	72 (52)	83 (77)	58 (60)	59 (63)
P (P <sub>2</sub> O <sub>5</sub> )	21 (66)	24 (81)	23 (71)	20 (78)
K (K <sub>2</sub> O)	41 (30)	49 (50)	41 (35)	43 (37)
Ca	6 (10)	4 (9)	2 (4)	12 (23)
Mg	5 (29)	6 (42)	4 (29)	6 (37)
S	5 (41)	6 (58)	5 (42)	5 (48)
	----- kg Mg <sup>-1</sup> -----			
N	26.3a	27.5a	22.8a	21.1a
P (P <sub>2</sub> O <sub>5</sub> )	7.7a	7.9a	9.2a	7.1a
K (K <sub>2</sub> O)	15.0a	16.1a	16.2a	15.4a
Ca	2.3b	1.4b	0.7c	4.3a
Mg	1.7a	1.8a	1.6a	2.0a
S	1.8b	2.0a	1.9b	1.9b
	----- g ha <sup>-1</sup> (%) <sup>(2)</sup> -----			
B	43 (20)	52 (31)	35 (17)	59 (33)
Cu	16 (51)	16 (73)	15 (62)	16 (58)
Fe	146 (13)	204 (23)	135 (12)	194 (39)
Mn	27 (25)	37 (46)	30 (32)	30 (30)
Zn	70 (46)	83 (61)	68 (52)	73 (58)
	----- g Mg <sup>-1</sup> -----			
B	15.8b	17.3a	13.7b	21.1a
Cu	5.9a	5.3a	6.0a	5.8a
Fe	53.2a	67.6a	52.9a	69.1a
Mn	9.9a	12.2a	11.9a	10.6a
Zn	25.5a	27.6a	26.8a	26.1a

<sup>(1)</sup>Mean values followed by equal letters, in the row, do not differ from each other by the Scott-Knott test, at 5% probability. <sup>(2)</sup>Values between parentheses represent the percentage of total nutrient accumulated in the grain.

The amounts of Ca exported – average of 4.0 kg ha<sup>-1</sup> – by previously released cultivars (Haag et al., 1967; Cobra Netto et al., 1971) were lower than those found in the present study for the TAA Dama and IPR Tuiuiú cultivars with an indeterminate growth habit (Table 4). In contrast, for the TAA Gol and BRS FC 104 cultivars with a determinate growth habit and a short cycle, the values were similar. In the case of Mg, the mean amount exported was around 3.0 kg ha<sup>-1</sup> for the cultivars studied in the 1960s and 1970s (Haag et al., 1967; Cobra Netto et al., 1971), which is a value lower than those obtained for all cultivars evaluated in the present work.

The greater exports of K<sub>2</sub>O, Ca, and Mg by the assessed cultivars, compared with previously studied ones, can be explained partially by the greater availability of these nutrients in the soil and by their high percentage in cation exchange capacity, showing the luxury consumption of those nutrients.

## Conclusions

1. At the end of the cycle of common bean (*Phaseolus vulgaris*) cultivars, regardless of the commercial group they belong to or of their growth habit, nutrient uptake is similar.

2. Cultivars with different growth habits (types I, II, and III) export similar amounts of N, P, K, Ca, Mg, Cu, Fe, Mn, and Zn.

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