Original Research Article

Biomass production and nutritional efficiency in *Eucalyptus* genotypes in the Pampa Biome

ABSTRACT

The objective of this work was to determine biomass production and nutritional efficiency in three eucalyptus genotypes in the Pampa - RS biome. For determination of biomass and nutritional characterization, 9 medium trees per genotype were sampled, separated in the components leaf, branch, bark, wood and root. The nutritional efficiency of the biomass components was determined using the biological utilization coefficient (BUC). The highest biomass production and mean annual increment were observed in the *Eucalyptus urograndis* hybrid with 158 Mg ha^{-1} and 47.2 m^3 ha^{-1}, followed by *Eucalyptus grandis* with 137 Mg ha^{-1} and 39.7 m^3 ha^{-1} and *Eucalyptus dunnii* with 122 Mg ha^{-1} and 23.2 m^3 ha^{-1}. For wood, the best nutritional efficiency was provided by *Eucalytpus urograndis* for P, Ca, and Mn, followed by *Eucalytpus grandis* for N and Mg, and *Eucalytpus dunnii* for K.

Keywords: forest soils, eucalyptus, forest nutrition.

1. INTRODUCTION

The eucalyptus tree occupies a prominent place among the different tree species planted in Brazil. Its raw material is considered of sustainable origin and supplies the various sectors: pulp and paper, energy, solid wood among others. As eucalyptus raw material is used, thousands of hectares of native forest, as well as its fauna and other natural resources are preserved [1].

Although the soils used for eucalyptus plantations in Brazil have low stocks of nutrients and organic matter and pH [2], Brazilian plantations have the highest global productivity [1]. This condition is intrinsically related to the adaptive and fast-growing silvicultural characteristics of the species in the different climate and soil conditions, as well as to the development of silvicultural techniques, management and genetic improvement [3,4].

Although eucalyptus is less demanding than other species and adapts more easily to the environment, some resources are determinant for maintaining and increasing productivity indices, such as water and nutrients. However, in addition to these elements, there is a great dynamism and variability in the productive behavior of the plantations caused by the population age, soil fertility, planting density and species [5,6].

The wide variety of Eucalyptus species and hybrids with different climatic and edaphic adaptation capacities, coupled with the ease of propagation, allow the adaptation of plantations to most regions of Brazil [2], even in places that previously did not present a silvicultural tradition with eucalyptus cultivation on a commercial scale, as in the west of Rio Grande do Sul, region of the present study.

During the management of a forest stand, all factors influencing growth need to be considered in order to maximize the productive capacity of the site, and in this sense Viera et al. [7] reiterates that the intensive management of eucalyptus plantations tends to increase the production and removal of nutrients from the system by the use of biomass, and that the distribution of nutrients in the components of the trees has great importance in the nutrition of forest stands managed in rotations successive. In addition, genotype selection based on its nutrient utilization efficiency, coupled with other factors intrinsic to the production environment, may contribute to productivity gains with eucalyptus cultivation [8,9].

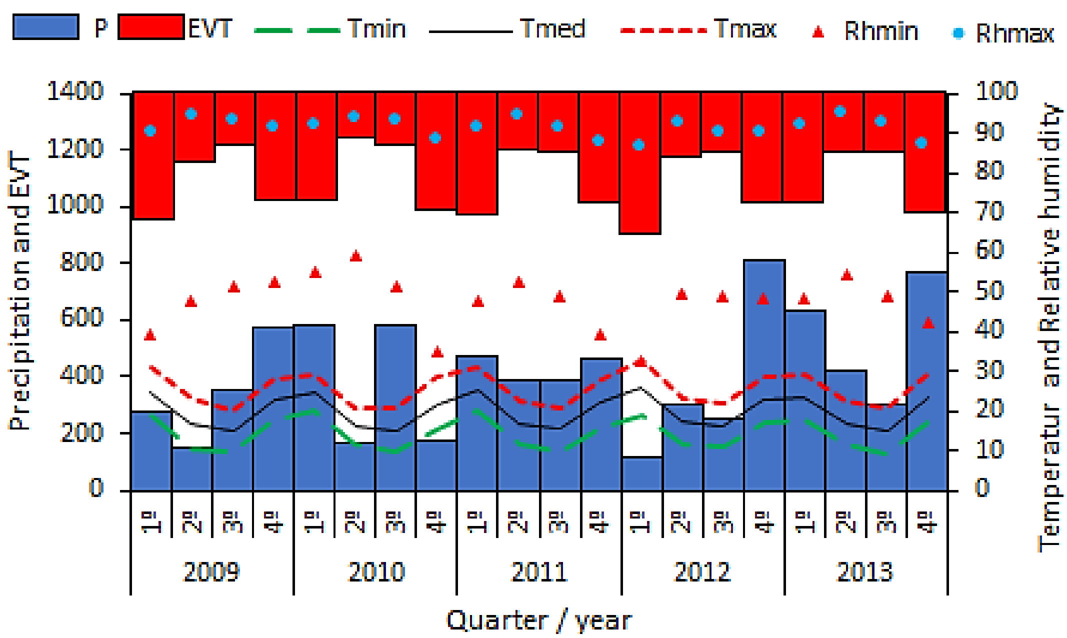
Therefore, the objective of this work was to estimate the biomass production and to determine the nutrient utilization efficiency in three eucalyptus genotypes in the Pampa - RS biome.

2. MATERIAL AND METHODS

2.1 Characterization of the experimental area

This study was carried out in the western region of Rio Grande do Sul, in the municipality of Alegrete. Three genetic materials, 4.5 years old, were evaluated: a clonal hybrid of *Eucalyptus urophylla* S.T. Blake x *Eucalyptus grandis* Hill ex Maiden - *Eucalytpus urograndis* 3301, located at Cabanha da Prata Farm, with central geographic coordinates of 55^o 32 '53" west longitude and 29^o 47'60'' south latitude; and two seminal materials, being: *Eucalyptus dunnii* Maiden and *Eucalyptus grandis* Hill ex Maiden, located at Fazenda Chica Barbosa, with central geographic coordinates of 55º 34'38 "W and 29º 46'43" S.

The climate of the region, according to the classification of Köppen, receives the denomination of Cfa " Subtropical Mesothermal" constantly humid. This climate is characterized by months of cold, with frosts from May to August, and intense heat, mainly in the months of January and February, with the average temperature of the month being warmer> 22°C and average annual temperature> 18 °C, with precipitation normally well distributed throughout the year, with no defined dry season and pluviometric indexes varying from 1250 to 1500 mm [10]. Figure 1 shows the meteorological diagram for the Alegrete region during the period of tree growth [11].



Where: P = precipitation; EVT = potential evapotranspiration; Tmin = minimum temperature; Tmed = average temperature; Tmax = maximum temperature; Rhmin = minimum relative humidity; Rhmax = maximum relative humidity.

Figure 1: Meteorological diagram for the Alegrete region during tree growth.

The planting of the areas was done manually in a typical Dystrophic Red Argisol. According to Streck et al. [12], this soil class involves deep soils and low natural fertility, are well drained, sand or frank sandy surface texture, followed by a sandy loam texture in the deepest horizons. Chemically they are soils with medium to high values of exchangeable bases, subject to leaching of mobile nutrients such as N and K, and presents moderate retrogradation of soluble phosphorus. Table 1 presents the characterization of soil attributes, specifically for the area of this work.

Table 1. Chemical and physical characteristics of the soil, in areas with eucalyptus genotypes, in Alegrete - RS.

Depth	OM	Clay	pH	CTC	Ca	Mg	P	K	S	B	Cu	Zn	V	m
(cm)	%		(H_2O)	efet.	cmol$_c$ dm^{-3}		mg dm^{-3}						%	
[1]0-20	1.4	19.0	4.4	3.4	0.9	1.0	2.3	38.7	5.3	0.3	5.0	3.2	15.0	41.4
20-40	1.3	19.0	4.4	4.8	1.6	0.7	0.8	17.3	6.3	0.2	7.0	1.5	10.6	52.2
40-100	1.1	33.0	4.6	5.5	2.8	0.9	0.6	12.7	6.0	0.3	7.0	1.0	20.0	32.7
[2]0-20	1.8	24.0	4.3	4.3	1.0	0.6	9.1	44.0	8.0	0.6	1.3	1.2	8.6	60.4
20-40	1.4	29.0	4.5	4.7	1.1	0.7	2.2	20.7	5.5	0.3	1.3	0.6	8.8	60.3
40-100	1.3	38.0	4.6	5.4	1.5	0.9	0.9	15.3	5.9	0.3	1.2	0.2	10.6	54.4

Where: OM= organic matter; [1]Soil of *Eucalyptus grandis* and *Eucalyptus dunnii*; [2]Soil of *Eucalyptus urograndis.*

Soil preparation was performed by subsoiling, incorporating 300 kg ha^{-1} of reactive natural phosphate (GAFSA, 12% P_2O_5 soluble in citric acid), followed by mild harrowing. The clone of *Eucalytpus urograndis* was planted at a spacing of 3.5 m x 2.5 m, totaling 1143 plants per hectare. Seedlings of *Eucalyptus dunnii* and *Eucalyptus grandis* were planted at a spacing of 3.5 m x 2.0 m, totaling 1428 plants per hectare. Three fertilizations were performed, the first 15 days after planting, using the NPK formula of 06-30-06 + 0.6% B, 110 g plant^{-1} divided into two sub-doses of 55 g and incorporated into 15 cm on each side of the seedling. The second fertilization was carried out at 90 days after planting, using the NPK formula of 20-05-20 + 0,2% B + 0.4% Zn, 122 g plant^{-1}, applied manually, on the surface, in the canopy projection. The third, at 270 days, using the formula N-P-K of 22-00-18 + 1% S + 0,3% B, 122 g plant^{-1}, applied mechanically, in continuous fillet, in the interline. At no time was the liming performed.

2.2 Experimental design and data collection

For the dendrometric characterization of the stand and the determination of the biomass above the soil and roots, initially, 3 plots of 350 m² were demarcated for each genotype evaluated, randomly distributed in an area of 10 hectares, where all diameters were measured at height breast (DBH) of live trees. In each plot, 3 trees were selected, being chosen by mean DBH - standard deviation, mean DBH and mean DBH + standard deviation, totaling 9 trees. The selected trees were sectioned at ground level, cubed according to the Smallian method, and fractionated in the components: leaf, branch, bark, wood and root.

For the biomass of the roots, 3 medium trees were selected, for each genotype, among the 9 used for the biomass above the soil. The root system of the trees was extracted by backhoe and manual excavation in the useful area (clone 8,75 m² and seminal material 7 m²) of each tree to the depth of 1 m.

The total wet biomass of each component was determined by field weighing. Samples were then collected from all trees and compartments and weighed with precision scale. The samples were leaf, branch and root, and three samples per tree for the wood and bark, distributed along the commercial stem (minimum diameter 8 cm), in the middle positions of the sections resulting from the division into three equal parts.

Drying and chemical analyzes of plant tissues were performed at the Forest Ecology Laboratory of the Department of Forest Engineering / UFSM, following the methodology of Miyazawa et al. [13].

Estimation of the biomass per hectare was determined by extrapolation based on the dry mass of each component per sampling unit. The amount of each nutrient was obtained by the product between the dry mass and the nutrient concentrations in each component. The estimate of the nutrient stock in the biomass per hectare was obtained by extrapolating the average stock of nutrients per compartment based on each sample unit.

The biological utilization coefficient (BUC) was calculated through the quotient between the biomass and the nutrient quantity per tree component, both with the same unit [7].

$$\text{BUC} = \frac{B\ (kg\ ha^{-1})}{N\ (kg\ ha^{-1})}$$

Where: B = biomass; N = nutrient

2.3 Statistics and Data Analysis

The statistical analysis was performed in the statistical program SAS [14] through the analysis of variance of the data referring to biomass, nutrients and coefficient of biological utilization. The contrast between the means was verified by the Tukey test, at the level of 5% probability of error, considering a completely randomized design, with each evaluated tree corresponding to a repetition for its respective components.

3. RESULTS AND DISCUSSION

3.1 Biomass production

The annual average increment (AAI) and wood biomass had significant differences between genotypes, but for biomass production *Eucalyptus grandis* and *Eucalyptus dunnii* did not differ. *Eucalyptus urograndis* presented to the IMA, productivity 16 and 51% higher in relation to *Eucalyptus grandis* and *Eucalyptus dunnii*, and also the same tendency for total biomass, being 14 and 23%, respectively (Table 2).

Table 2. Annual average increment and biomass in eucalyptus genotypes, at 4.5 years of age, in Alegrete - RS.

Genotype	N	[3]AAI (m^3 ha^{-1} $year^{-1}$)	Biomass (Mg ha^{-1})					
			Wood	Bark	Leaf	Branch	Root	Total
E. grandis	1035	39.7b	89.4b [4](65)	9.6a (7)	6.4a (5)	11.2a (8)	20.1ab (15)	136.7b
E. dunnii	1165	23.2c	76.7c (63)	9.1a (8)	5.3a (4)	13.4a (11)	17.4b (14)	121.9b
E. urograndis	932	47.2a	109.9a (70)	10.1a (6)	3.4b (2)	11.3a (7)	23.4a (15)	158.1a

Where: N = number of trees per hectare; AAI = average annual increment; Values in parentheses refer to the relative partition (%); Same letters in the vertical do not differ statistically between species for biomass of the components and AAI at the 0.05 level of significance by the Tukey test.

The results is probably associated with the genetic improvement of *Eucalyptus urograndis*, in relation to the seminal origin of *Eucalyptus dunnii* and *Eucalyptus grandis*, corroborating the concept that hybridization provides the improvement of forest characteristics [15], as well as higher values observed in the soil attributes with *Eucalyptus urograndis*, especially clay, P, K and S (Table 1).

In average terms, for the relative partition of the total biomass, the wood represents 66% of the tree biomass, and when considering only the aboveground biomass this condition rises to 76%. The distribution of the biomass between the respective components presented the same tendency being wood > root > branch > bark > leaf, which corresponds to the one verified by several authors [7,16,17,18].

The values of aboveground biomass production found by Santana et al [19], studying the hybrid of *Eucalyptus urograndis* and *Eucalyptus grandis*, at 4.5 years of age in eight regions of Brazil, ranged from 44.5 Mg ha^{-1} to 145 Mg ha^{-1}. Except for the region of São José dos Campos - SP, the other observed values differed from this work. The same condition was verified by Schumacher and Caldeira [16], with *Eucalyptus globulus* at 4 years of age, in Butiá - RS, where they verified the production of 83.2 Mg ha^{-1} of biomass; and also by Beulch [20] evaluating the production of the clone of *Eucalyptus saligna*, at 4 years of age, in São Francisco de Assis - RS, and Silva [21] evaluating *Eucalyptus dunnii* at 4 years of age in Alegrete - RS, which verified a yield of 88.81 Mg ha^{-1} and 44.5 Mg ha^{-1} of biomass, respectively.

The variability of productivity verified in this study, in relation to the other regions, can be explained by the different types of soils cultivated with eucalyptus, which have varied nutrient contents [5]. Furthermore, factors related to genetic improvement [15], water regime, planting density and management techniques are directly related to the production capacity of the species [22,23,24].

3.2 Quantity and efficiency of nutrient utilization

Analyzing the total amounts of nutrients allocated in the biomass (Figure 2), it is observed that, among the genotypes, the wood of the trunk presented the largest quantities of N and K (except the leaf of *Eucalyptus grandis* for N), and the bark presented the largest Amounts of P, Ca, Mg and S, (except for *Eucalyptus grandis* trunk wood for P).

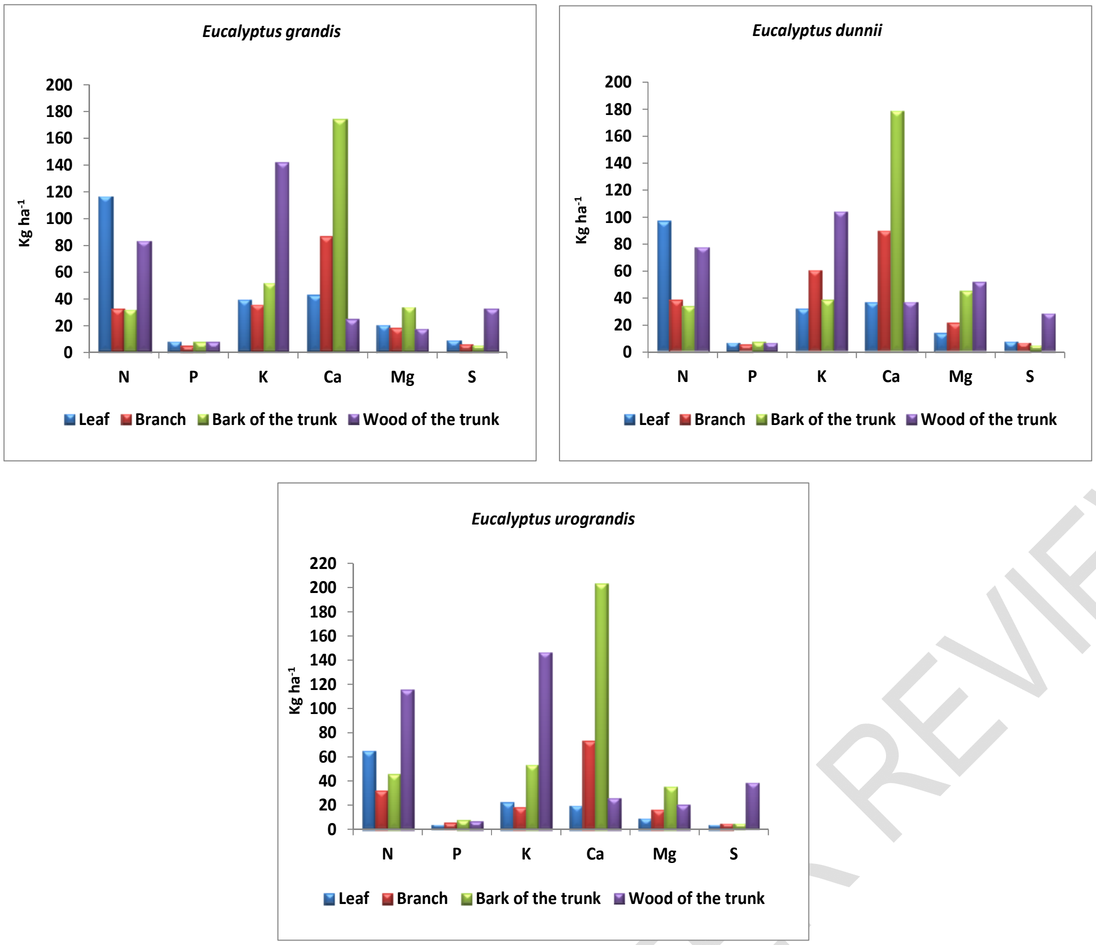


Figure 2. Amount of nutrients in different biomass components of eucalyptus genotypes in Alegrete - RS.

On average, was accumulated in the biomass 251 kg ha^{-1} of N, 22 kg ha^{-1} of P, 247 kg ha^{-1} of K, 332 kg ha^{-1} of Ca, 99 kg ha^{-1} of Mg and 45 kg ha^{-1} S, with the following order for nutrients Ca > N > K > Mg > S > P. This behavior was also found by Benatti [25], with the *Eucalytpus urograndis* clone at 6.5 years of age, in MG, and Cunha et al. [26], with *Eucalyptus grandis*, at the age of 8 years, in the North Fluminense-RJ. In a study with different eucalyptus genotypes, in the Jequitinhonha Valley, in MG, Faria et al. [9] verified the sequence N > P > K > Ca > MG, which was also observed by Hernandéz et al. [23] evaluating *Eucalyptus dunnii* at 9 years of age in Uruguay, a result that differs from that found in this work.

The variation of nutrient accumulation, from element to element, in the components of tree biomass, according to Schumacher & Caldeira [16], occurs due to the nutritional characteristics of each species, the different levels of soil fertility and Age of the stand.

The amount of nutrients in the bark and canopy (branches, leaves and tree tops), expresses the importance of the presence of these components in the post-harvest site. In the present study, it was observed that the removal of only wood from the trunk reduces the export of nutrients from the system, mainly in areas of low fertility, contributing to the maintenance and productive capacity of the soil [7,18,27].

With the harvesting only of the wood of the trunk the maintenance of the accumulated nutrients in the other components of the biomass of 63% of the N, 74% of the P, 47% of the K, 91% of the Ca, 73% of the Mg and 34% of the S, and considering the harvest of the wood plus the bark, this permanence decreases to 49% of N, 44% of P, 28% of K, 34% of Ca, 34% of Mg and 24% of S.

There were significant differences between the genotypes for the biological utilization coefficient. The best conversion rates were presented by trunk wood, with a distribution tendency for the BUC, in the following order: P> Mg> Ca> S> N> K (Table 3).

Table 3. Biological utilization coefficient of nutrients (kg of biomass / kg of nutrient) for eucalyptus genotypes in Alegrete - RS.

Genotype	Component	Biological Utilization Coefficient BUC					
		N	P	K	Ca	Mg	S
E. grandis	Leaf	54a	842b	165ab	158a	323b	744b
	Branch	353a	2732b	325b	136a	636a	2074a
	Bark	305a	1846a	186b	54a	287a	2133a
	Wood	1067a	12247b	607a	3605ab	5623a	2820b
	Root	276ab	3466a	310b	206b	1827b	1415a
E. dunnii	Leaf	57a	981a	166a	146a	411a	883a
	Branch	360a	4621a	238a	160a	654a	2127a
	Bark	278a	1750ab	254a	51a	208b	1936a
	Wood	1049a	12574b	776a	2107b	1546b	2905b
	Root	348a	3053a	572a	154b	883c	1832a
E. urograndis	Leaf	63a	810b	148b	168a	362ab	829b
	Branch	343a	2173b	595b	149a	673a	2260a
	Bark	215b	1312b	185b	48a	279a	416a
	Wood	928a	17172a	728a	4195a	5309a	4697a
	Root	246b	3900a	629ab	305a	2364a	1733a

Where: Equal vertical letters do not differ statistically between the genotypes, and their respective biomass components, at the 0.05 level of significance, by the Tukey test.

The distribution observed for the BUC in wood was not verified by Beulch [20], in a study carried out in the city of São Francisco de Assis - RS, with *Eucalyptus saligna*, at age 4, S> P> Mg> Ca> N> K, and neither by Viera et al. [7] evaluating the hybrid of *Eucalyptus urophylla* x *Eucalyptus globulus*, at age 10, in the municipality of Eldorado do Sul - RS, P> S> Mg> Ca> N> K.

According to Santana et al. [8], the variation observed in BUC among the genotypes of this work can be explained by the absence of optimal or critical nutritional balance between soil, plant and nutrients, as well as the relationships water and a possible limitation of one or more nutrients in this environment.

From the nutritional point of view, it is desired to select genotypes that potentiate the production of biomass per unit of nutrient absorbed [28]. However, the implantation of stands with genetic materials that present an adequate BUC for all nutrients, in one place, in practice is unlikely [8].

Comparing the BUC in the wood (Table 3), with values considered critical by Barros et al. [29], in the NUTRICALC software: P - 12000 kg, K - 1000 kg, Ca - 600 kg and Mg - 3000 kg of trunk biomass / kg of nutrient, the average values for P, Ca and Mg, and lower values for K, relative to the critical values.

In this context, Santana et al. [8] argue that high BUC values in relation to critical BUC indicate that the evaluated nutrient may have limited growth in the current rotation, and possibly limit growth in future rotations, but this condition may be mitigated by nutritional replacement via mineral fertilization in quantities that meet the demand of eucalyptus.

The BUC values for P and Mg are similar to those observed by Faria et al. [9], in a study with 11 interspecific hybrids of *Eucalyptus* spp, in the region of the Jequitinhonha Valley in Minas Gerais, except for K and Ca that presented lower values. These authors point out that the quality of the sites is one of the most important factors to consider in the selection of superior genotypes for the BUC characteristic, due to the differences intrinsic to each species. In addition, Barros & Novais [30] explain that the BUC for a given nutrient may vary as its soil availability changes, and that BUC in general increases by reducing its soil availability.

5. CONCLUSION

The highest biomass production was provided by *Eucalyptus urograndis* followed by *Eucalytpus grandis* and *Eucalytpus dunnii*. The same behavior was verified in relation to nutrient utilization efficiency, with the best values for BUC in the wood, indicating a tendency of future limitation of productivity provided by P in *Eucalytpus urograndis* and Ca for the three genotypes, if not adequate nutritional replacement.

Despite the lower biomass production verified in *Eucalyptus dunnii*, there is an opportunity to increase productivity through investments in genetic improvement in the wild or through hybridization, considering the technological properties of wood for the production of cellulose and the good adaptation to regions with high occurrence of frost. The observed BUC values corroborate its application as an indicator in the selection of the best genotypes to be implanted in the different sites, also indicating the possibility of management optimization, nutritional sustainability and a possible reduction of the operational costs with the acquisition of fertilizers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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