Scientific Paper

Agronomic and nutritional performance of cultivated species in a Voisin rational grazing system, in Panama

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Abstract

Objective: To characterize the agronomic performance and chemical composition of cultivated species in a Voisin rational grazing system, in the humid tropic of Los Santos, Panama.

Materials and Methods: The yield and nutritional value of a group of cultivated species were evaluated, with 24 paddocks and 1,9 days of average occupation. The system was grazed with 53 Zebu-based steers and their F1 and F2 crossings (Zebu x Holstein). The main indicators measured were: total forage production (kg DM/ha/rotation), forage supply per species and percentages of DM, CP, ADF, NDF, $IVDMD_{30}$, ME, Ash, Ca and P. The data were processed using simple classification variance analysis. The statistical package IBM® SPSS® Statistics version 22 was used.

Results: Forage production varied between 3 344 and 4 442 kg DM/ha/rotation. The highest pasture yield was obtained in the rainy season. The best yields ($p < 0,001$) were obtained in the genus *Megathyrsus* (cvs. Tanzania and Massai), with offers of 34,9 and 31,9 t DM/ha/year, higher than those of the different *Urochloa* cvs. Regarding the availability of DM/ha/rotation, the lowest values were achieved in the cultivars Toledo and Humidicola. The quality was higher in the rainy season. The high average DM in the dry season (40,80 %) conditioned low CP values (6,85 %), low energy content (1,57 Mcal/kg), low digestibility (55,7 %) and high contents of NDF (74,2%).

Conclusions: The average yield and pasture supply of the species were acceptable for the prevailing edaphoclimatic conditions in the ecosystem, since no irrigation or external fertilization was used; although they decreased in the dry season, as well as the nutritional quality. The genus *Megathyrsus* stood out for its better production indicators; while *Arachis pintoi* Krapov. & W.C. Greg stood out for its high nutritional value.

Keywords: chemical composition, supply, biomass production

Introduction

In Latin America, animal husbandry plays a preponderant role, due to its contributions to the economy, food security, nutrition, poverty reduction and environmental sustainability (Ezquerro-Cañete, 2022). In this context, naturalized pastures cover most of the grazing areas and are the basis of cattle production at the regional level (Triana-González *et al*., 2016). However, they are characterized by low yields and poor quality, which is denoted by their low content of crude protein and soluble carbohydrates, high fiber concentration, low digestibility and low content of metabolizable energy (López-Vigoa *et al*., 2017).

Given the low productivity and quality of native pastures and their gradual degradation, as well as in order to increase the carrying capacity in animal husbandry systems, it is essential in intensive production systems the establishment of cultivated pastures with introduced grasses and legumes.

Megathyrsus maximus (Jacq.) B. K. Simon shows great forage production potential, wide range of adaptation to climate and soil, drought tolerance and excellent forage quality. In addition, it is ideal for silvopastoral systems because it tolerates shade very well (Zambrano-Mejía, 2016). Also *Urochloa* (commonly called brachiaria) is one of the most important tropical grasses among those distributed throughout the tropics. Most of the commercial species of *Urochloa* are adapted to acid soils, and have lower internal requirements (especially in P, Ca and Mg) than other commercial grasses (Noreña, 2017).

The forage peanut, associated with stoloniferous grasses, has allowed increases of 15,0 % in milk and 20,0 % in meat in controlled experiments by improving the animal diet and the biological activity of the soil, due to nitrogen fixation and to the higher presence of earthworms in associated grasslands (Andrade-Yucailla *et al*., 2016; Báez-Lizarazo, 2018).

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In general, superiority has been reported in introduced or cultivated pastures, with regards to natural pastures, when analyzing productivity, nutritional value, resistance to soil stressing factors, pests and diseases, as well as the persistence and productive indicators in their evaluation with animals.

In this sense, Milera-Rodríguez (2018) summarized that the yields of DM/ha/year, without the use of fertilizers or irrigation (results that serve as a basis for agroecological systems) were higher by 44,6 % in commercial varieties, with values in the ranges of 11,6-19,5; 10,0-12,0 and 8,0-16,5 t of DM for tillering, erect and creeping plants, respectively, compared with 6,0-8,0 t in native pastures.

Considering these antecedents, this research was conducted, with the purpose of characterizing the agronomic performance and chemical composition of cultivated species in a rational Voisin grazing system, in the humid tropics of Los Santos, Panama.

Materials and Methods

Location and duration of the trial. The research was carried out at the Pajonales cattle farm, located at km 4,5 of the Nuario Village, Las Tablas District, Los Santos Province, Republic of Panama, at UTM coordinates N 575584, W 831759, at an altitude of 484 m.a.s.l.

Edaphoclimatic characteristics. The edaphoclimatic characteristics of the farm, as well as the aspects of pasture and animal management have been described by Domínguez-Escudero *et al*. (2021).

Plant community. The cultivated pastures that predominated in the system were the grasses *Cynodon dactylon* L. Pers cv. Alicia, *Digitaria didactyla* Willd cv. Swazi, *Urochloa arrecta* Morrone & Zuloaga cv. Tanner, *M. maximus* cv. Tanzania, *M. maximus* cv. Mombaza, *M. maximus* x *Megathyrsus infestum* cv. Massai, *Urochloa brizantha* R.D. Webster cv. CIAT-6780, *U. brizantha* cv. CIAT-26110, *Urochloa decumbens* R.D. Webster cv. CIAT-606, *Urochloa humidicola* Morrone & Zuloaga cv. CIAT-679, *U. humidicola* cv. CIAT-6133, hybrid *Urochloa* CIAT-36087, and the legume *Arachis pintoi* Krapov. & W.C. Greg CV. CIAT-18744. The details about planting and their establishment appear in the publication by Domínguez-Escudero *et al*. (2021).

Measurements and estimations

Forage production. The indicators total forage production (kg DM/ha/bimonthly and average rotation) and forage supply per species (t DM/ha/year and per rotation) were estimated, using the agile method proposed by Martínez *et al*. (1990). The cutting height in erect plants was 20 cm and 10 cm in creeping ones. The pasture height (cm) upon the entrance and exit of the animals from the paddock was also measured with a graduated metric tape, at a rate of 30 observations per paddock, as well as the percentage of pasture utilization.

Chemical composition. The chemical composition of the pasture was estimated bimonthly, according to the NIRS technology (Rivera-Rivera and Alba-Maldonado, 2017). The indicators DM, CP, ADF, NDF, $IVDMD_{30}$, ash, Ca and P and ME were measured.

Statistical analysis. The data were processed by means of a simple classification ANOVA, after it was verified whether they fulfilled the theoretical assumptions of the variance analysis: the homogeneity of the variance by Levene's test (1960) and the normality of errors by means of the Shapiro and Wilk (1965) test. In the cases in which significant differences among species were found, Duncan's multiple comparison test was used, with 95 % confidence.

Results and Discussion

Table 1 shows the total forage production per two-month period, which varied between 3 344 and 4 442 kg DM/ha/rotation. The highest values were obtained ($p < 0,001$) in the last two-month period of the rainy season and in the first one (January-February) of the year 2020. The latter coincided with the dry season. The high biomass production in January and February, months in which no rainfall occurred, could be due to the fact that, in the previous months (November and December, 2019), the accumulated rainfall was above 100 mm. Added to this is the resting period (60 days) that the pastures had in the November-December two-month period, ten days above the average for the different species (Domínguez-Escudero *et al*., 2021). Therefore, a higher amount of biomass and reserves were accumulated in the pastures, which corroborates the report by Senra *et al*. (2005).

Regarding the most representative grazing species (table 2), the best yields were obtained in the genus *Megathyrsus*, represented by cvs. Tanzania and Massai, with 34,9 and 31,9 t DM/ha/year, which differed significantly ($p < 0,001$) from the different *Urochloa* cvs. As for the availability of DM/ha/rotation, the lowest values were achieved in the Toledo and Llanero cultivars, with less than 4,0 t.

Milera-Rodriguez *et al*. (2013) stated that tillering grasses, such as the genus *Megathyrsus*, have a higher average yield than creeping grasses (*Urochloa*), which was proven in this study, where soil conditions (pH 5,6

Table 1. Two-month production of forage in the Voisin rotational grazing systems (kg DM/ha/rotation).

Indicator	May-June	July-August	September-October	November December	January-February	$\overline{X}$	SD
Forage production	3 344[d]	3 531[c]	3 887[b]	4 287[a]	4 442[a]	3 898	444

a, b, c and d; Means with different superscripts differ at p < 0,05
p < 0,001***

Table 2. Yield of the most representative cultivars of grazing.

Variable	Tanzania	Massai	Mulato	Toledo	LLanero	$\overline{X}$	SE±
Forage supply, t DM/ha/year	34,9[a]	31,9[ab]	25,1[b]	15,7[c]	12,2[c]	24,96	2,06***
Forage supply, t DM/ha/rotation	5,5[a]	5,7[a]	5,0[ab]	3,9[bc]	2,8[c]	4,79	0,25***
Utilization, %	72,0[ab]	75,0[ab]	69,0[b]	77,0[ab]	80,0[a]	75,0	1,26*
Occupation, days	1,7	1,9	2,3	2,0	1,8	1,9	0,10
Height entrance, cm	93,0[b]	81,0[bc]	71,0[c]	104,0[a]	70,0[c]	87,0	2,87***
Height exit, cm	33,0[bc]	27,0[b]	30,0[b]	37,0[c]	19,0[a]	30,0	1,41***

a, b, c, d and e: Means with different superscripts in each row differ at p <0,05
p < 0,05*; p < 0,001***

and loam-sandy texture) favored their persistence and DM production with regards to brachiarias, which need soils with lower pH and better drainage to express their maximum potential. This result rules out the possible competition among species or management factors that propitiated better conditions for Guinea grass, because the paddocks were grazed from the determination of the optimal harvest point (OHP), as recommended by Pinheiro (2011). In addition, the occupation of the paddocks was managed based on the use of the pasture by the animals and the principles of the second law of Voisin grazing were respected.

When analyzing these results and those obtained by Silva *et al*. (2016), who evaluated the yield and morphological characteristics of two cultivars of *Megathyrsus* (Tanzania and Mombaza) and three of *Urochloa* (*U. brizantha* cv. Xaraes, *U. decumbens* cv. Basilisk and *U. brizantha* cv. Marandú), it can be verified that the above-cited authors did not find significant differences among species, under controlled conditions and with chemical fertilization. This limits the real analysis about the possible interactions that occur in grazing among species and animals and their adaptation to different management, soil and climate conditions.

In other works on grazing, the yield results of these species are variable, which reaffirms the influence exerted by edaphoclimatic and management factors on pasture production. The data from this study are higher than those reported by Valle *et al*. (2016) with *Megathyrsus* and *Urochloa*, who achieved 18,7 and 15,4 t DM/ha/year. Earlier, Valerio *et al*. (2013) in Tanzania and Humidicola referred 21,64 and 24,20 t DM/ha/year.

Silva (2016) reported productions of 4,1-5,2 t DM/ha per rotation cycle in the cultivar Massai, which are similar to those of this study. However, in this case, high doses of fertilizers were used. Meanwhile, in the hybrids cvs. Mulato and Mulato II, Cruz and Pereda-Mousso (2018) obtained yields of 23,86 and 25,06 t DM/ha/year, very close to those of this research.

The percentage of utilization in all the species was high, without differences among them, which proved deep grazing, in accordance with the average instantaneous stocking rate used (68 LAU/ha), the occupation time of the paddocks (between 1,7 and 2,3 days) and the average grazing intensity (148 LAU/ha/day) applied for these species (Domínguez-Escudero *et al*., 2021).

The animals grazed a horizon with a depth that varied between 41,0 cm (Mulato) and 67,0 cm (Toledo), which indicates that the intake must have been high, since the highest percentage of leaves is found in the strata of more than 30 cm of height, a more accessible zone for animals (Milera-Rodríguez *et al*., 2019). This shows the importance of grazing intensity, as a biotic factor that directly affects pasture yield and height, as well as the quality of pasture available in a pastoral environment, which subsequently influences intake per animal and per area.

In this research, the pasture height upon the exit of the animals from the paddocks was between 19,0 and 37,0 cm, with differences among the varieties, which is consistent with their growth habit and the pastureland structure.

In this regard, Páez *et al.* (1995) pointed out that for *M. maximus* heights between 40,0 and 60,0 cm (higher than the ones found here) provide a greater residual fraction of leaves and, therefore, a photosynthetically active area and lower mobilization of photoassimilates from the roots to the regrowth.

However, Villalba *et al.* (2014) stated that in this type of grazing system it is important that this consumption is done more thoroughly, up to a height between 3,0 and 5,0 cm. This could limit voluntary intake, because grazing horizons lower than 10,0 cm correspond to important restrictions in the formation of the bite, which results in a significant reduction in its size and higher bite rate, although there is a high proportion of leaves in the consumed biomass.

Euclides *et al.* (2018), when evaluating three grazing intensities (15, 25 and 30 cm of grass height) found a higher percentage of leaves, better leaf-stem ratio, as well as higher CP content and *in vitro* organic matter digestibility (IVOMD) in the middle and upper strata. In the grazing horizon, the leaf-stem ratio over 15,0 cm suggests a better pasture cover structure for selection by grazing animals.

It is estimated that the yields of these species were acceptable for the edaphoclimatic conditions of the studied ecosystem, if it is taken into account that neither irrigation nor external fertilization was used. However, the contribution of rainfall (1 490 mm in eight months of the year) and that of excreta in the paddocks must have been decisive in these results, which are in correspondence with those reported by Milera-Rodríguez *et al.* (2013) for the conditions of 24 locations in Cuba.

Table 3 shows the quality indicators of the pastures per season. The DM content here had an average value of 22,1 % in the rainy season, with no statistical difference among the pasture species. These results are lower than those reported by Canchila *et al.* (2009) when they evaluating the bromatological composition of 24 accessions of *Brachiaria* spp, (currently *Urochloa*), and obtained an average of 24,6 % on acid soils with low fertilization. However, they are higher than those reported by Silva *et al.* (2016) in cvs. Tanzania and Toledo (19,20 and 21,33 %, respectively), with 21 days of regrowth and fertilization.

On the contrary, during the dry season, the DM average in the pastures showed a high percentage (40,8 %), due to the fact that they had between 50 and 60 days of resting, for which it was decided to prolong the occupation time of the paddocks up to 4 days, to try to increase the intake of forage, which was lignified and showed low quality.

In this regard, Calzada-Marín *et al.* (2018) argued that a long interval between defoliations produces higher accumulation of fibrous material, low nutritional value and lower voluntary intake. The cause could be given by the decrease in the rate of appearance and elongation of the leaves, as the resting time increased. It could also be due to the water deficiency of the season, which is expressed in a lower capacity of the plant to emit leaves, since there is a lower tissue turnover rate. This conditioned its low quality and was shown in the CP value (6,9 %), energy content (1,57 Mcal/kg), low digestibility (55,7 %) and high NDF content (74,2 %).

Leon *et al.* (2018) state that in the case of these megathermal pastures, which concentrate their production with very fast growth in the summer, when their resting is prolonged, the forage loses its quality very quickly. This is ascribed to a higher production of biomass of stems and dead material of the pasture, which can limit the animal response to loss of weight or body condition.

The CP content in the rainy season was significantly higher ($p < 0,001$) in the forage peanut (18,6 %) compared with the grasses (its content was not determined in the dry season), although the values for the latter, in general, were close to 10,0 % as average. The higher contents in *A. pintoi* are typical of tropical pastures, where legumes surpass grasses in this variable (INATEC, 2016). The genus *Megathyrsus* (11,01-11,43 %) tended to be slightly higher than the species of the genus *Urochloa* (9,47-9,53 %), although there were no significant differences, except in cv. Mulato II, which differed from cv. Massai.

The results for the rainy season were higher than those found by Canchila *et al.* (2009) and Canchila *et al.* (2011) in *U. humidicola*, with CP contents of 6,5-9,2 %. They were also above those obtained by Ortega-Aguirre *et al.* (2015) in Tanzania, Mulato and Toledo (10,7; 7,7 and 9,6; respectively). In

Table 3. Performance of the chemical composition per cultivar and season.

Cultivar	DM,%	CP, %	ADF,%	NDF, %	$IVDMD_{30}$, %	ME, Mcal/kg	Ash, %	Ca, %	P, %
Rainy season									
Tanzania	22,7	$11,1^{bc}$	$42,3^{b}$	$72,7^{b}$	$69,7^{b}$	$1,9^{b}$	$12,2^{a}$	$0,24^{b}$	$0,22^{b}$
Massai	20,4	$11,4^{b}$	$44,0^{b}$	$79,1^{c}$	$67,7^{b}$	$1,9^{b}$	$10,1^{b}$	$0,03^{d}$	$0,17^{c}$
Mulato	22,4	$8,2^{c}$	$39,2^{b}$	$71,9^{b}$	$65,0^{b}$	$1,93^{b}$	$8,7^{c}$	$0,17^{bc}$	$0,17^{c}$
Toledo	24,7	$9,5^{bc}$	$39,5^{b}$	$74,4^{bc}$	$66,0^{b}$	$1,9^{b}$	$9,0^{bc}$	$0,06^{cd}$	$0,19^{bc}$
Llanero	18,6	$9,5^{bc}$	$41,2^{b}$	$76,7^{bc}$	$65,3^{b}$	$1,9^{b}$	$9,0^{bc}$	$0,03^{d}$	$0,19^{bc}$
Arachis CIAT-18744	23,0	$18,6^{a}$	$31,3^{a}$	$43,5^{a}$	$80,0^{a}$	$2,2^{a}$	$11,9^{a}$	$1,61^{a}$	$0,28^{a}$
Mean	22,1	11,3	39,6	70,0	68,7	1,96	10,1	0,3	0,2
SE±	0,92	0,85 ***	1,09 *	2,82 ***	1,27 ***	0,03 ***	0,35 ***	0,13 ***	0,01 ***
Dry season									
Tanzania	$42,5^{b}$	6,6	49,3	73,3	59,0	$1,7^{a}$	$10,8^{a}$	$0,21^{a}$	$0,14^{ab}$
Massai	$44,1^{b}$	7,0	49,0	79,4	55,0	$1,5^{b}$	$10,4^{a}$	$0,06^{b}$	$0,17^{a}$
Mulato	$46,2^{b}$	6,6	43,0	73,7	54,0	$1,7^{a}$	$7,6^{b}$	$0,11^{b}$	$0,12^{b}$
Llanero	$30,4^{a}$	7,2	49,7	70,5	55,0	$1,4^{b}$	$10,6^{a}$	$0,06^{b}$	$0,13^{ab}$
Mean	40,8	6,9	47,8	74,2	55,8	1,6	9,9	0,11	0,14
SE±	3,76 ***	0,83	1,32	2,97	0,88	0,04 *	0,48 *	0,01 **	0,00

a, b, c and d: Means with different superscripts in each clumn differ at p < 0,05 (Duncan,1955)
p < 0,05; p < 0,01; p < 0,001

addition, they exceeded those reported by Silva *et al*. (2016) for cvs. Tanzania and Toledo, which were fertilized (8,60-8,56, respectively). However, they are lower than those obtained by Tsuzukibashi *et al*. (2016) in cv. Toledo (10,1-9,8 %), with 35-49 days of regrowth and fertilization. They are also below those reported by Cruz and Pereda-Mousso (2018) in Mulato II (10,2 and 11,1 % in the rainy and dry seasons, respectively). On the other hand, Núñez-Delgado (2017) reported protein percentages between 14 and 16 % in *Megathyrsus*, at 30 days of regrowth.

Regarding the dry season, there were no significant differences among the grasses (6,6-7,2 %). In this case, the values were low and were in correspondence with the report by Condori (2015) about the significant negative correlations between the percentage of DM and CP of the pastures. That is: the species that have high DM percentages will show low CP and ash concentrations.

The fiber values in the rainy season showed significant differences (p < 0,001) between the legume (31,3-43,5 %) and the grasses (39,2-44,0 % and 71,9-76,7 %). for ADF and NDF, respectively. Among the grasses, there were only differences for the NDF variable of cv. Massai, which showed a high percentage (79,1). Meanwhile, for the dry season there were no significant differences (43-49,7 % and 70,5-79,4 %) for ADF and NDF, respectively. These values were higher than those reported by López-Vigoa *et al*. (2019) in *M. maximus* cv. Likoni (35,2-34,4% and 68,7-68,0 %) for ADF and NDF, respectively. They were lower than those referred by Rodríguez and Lara (2018) in cv. Tanzania (42,9-57,6 % and 74,9-80,7 %) for the rainy and dry season, respectively, both in silvopastoral systems in association with *Leucaena leucocephala* (Lam.) de Witt. However, they were similar to those obtained by Ortega *et al*. (2015) in the rainy season for Tanzania, Mulato and Toledo (66,3-70,0-78,0 %, respectively).

The IVDMD at 30 hours was high in the rainy season, with significant differences (p < 0,001) between *A. pintoi* (80,0 %) and the grasses, which did not show differences among them (65,0-69,7 %). These values are within the range recommended by Arango *et al*. (2016) for *Megathyrsus* (60,0 -70,0 %), and are similar to those reported by Santiago-Hernández *et al*.

(2016) in a system of *M. maximus* cvs. Tanzania-Mombaza (65,0 %) associated with *Melia azedarach* L. They are also similar to those found by Olivera-Castro *et al*. (2018) in *U. brizantha* CIAT-26646 (65,1 %) and those registered by Tsuzukibashi *et al*. (2016) in cv. Toledo, who reported 68,29 and 66,68 %, at days 35-49 regrowth and fertilization. However, they were slightly higher in the rainy season (62,0 %) and lower in the dry season (60,0 %) compared the results obtained by Frota *et al*. (2017) in *M. maximus* cv. Mombaza associated with *Attalea speciosa* Mart. In the dry season, the digestibility was lower, although there were no significant differences among the grasses, with values that varied between 54,0 and 59,0 %. This result may be related to the higher NDF content at this season, because this indicator depends on the degree of lignification of the forage plant cell wall.

ME was relatively low in both seasons for the grasses (1,85-1,94 Mcal/kg), which differed ($p < 0,001$) from *A. pintoi* (2,24 Mcal/kg) in the rainy season. In the dry season there were significant differences ($p < 0,05$) among the grasses, with the best values (1,68-1,70 Mcal/kg) for the cvs. Mulato and Tanzania; while cvs. Llanero and Massai showed values below 1,5 Mcal/kg. These results are in correspondence with the high fiber values (ADF and NDF) found in the different species (Condori, 2015), because the pastures with high fiber content have lower fat content and, therefore, low energy and an inversely proportional relation. However, these values were higher than those reached by Canchila *et al*. (2011) in *U. humidicola* (1,72 Mcal/kg) in acid soils, with low fertilization. They were also higher than those reported by López-Vigoa *et al*. (2019) in Guinea grass cv. Likoni, associated with *L. leucocephala* (1,87 Mcal/kg DM).

The ash contents were high in both seasons and showed significant differences among species, with higher values ($p < 0,001$) for Tanzania and *A. pintoi* (12,18 -11,87 %, respectively). In the dry season, cvs. Massai, Llanero and Tanzania differed significantly ($p < 0,05$) from cv. Mulatto II (7,60 %). These results were lower than those reported by Ortega-Aguirre *et al*. (2015) in the rainy season, when cvs. Tanzania, Mulato and Toledo presented values of 15,14; 11,29 and 11,40 %, respectively. However, they were higher than those found by Canchila *et al*. (2009) in *U. humidicola*, (7,5 %), and the ones referred by Fernandes *et al*. (2020) in Massai, who refer contents of 5,8 %.

Conclusions

The average yield and pasture supply of the species under study were acceptable for the prevailing edaphoclimatic conditions in the ecosystem, since no irrigation or external fertilization was used. However, the decrease in yields and quality of the different species in the dry season should be highlighted, due to the high DM contents and fibrous fractions of the plants. Among the grasses, the genus *Megathyrsus* stood out for its best production indicators; while the legume *A. pintoi* stood out for its high nutritional value.

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Authors' contribution

- Jesús Manuel Iglesias-Gómez. Design of the research, data analysis and interpretation, manuscript writing and revision.
- José Miguel Alejandro Domínguez-Escudero: Design and setting up of the research, data analysis and interpretation, manuscript writing and revision.
- Hilda Beatriz Wencomo-Cardenas. Data analysis and interpretation and manuscript revision.
- Yuseika Olivera-Castro. Data analysis and interpretation and manuscript revision.
- Odalys Caridad Toral-Pérez: Data analysis and interpretation and manuscript revision.
- Milagros de la Caridad Milera-Rodríguez. Data analysis and interpretation, technical advice.

Conflict of interests

The authors declare that there is no conflict of interests among them.

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