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Araştırma Makalesi / Research Article

Nutrient Content of Some Wild Plants Growing in Köyceğiz Special Environmental Protection Area (Sandras Mountain)

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Abstract

In this study, the mineral content of some plant species widely distributed around the Chromium mine area in the Sandras Mountain Gökçeova region and the physical and chemical properties of the soils were investigated. The soil samples were analyzed for its pH, $CaCO_3$, EC, sand, organic matter and Macro- micro elements while shoots and roots were determined for its macro and micro elements. The results obtained from soil analysis showed suitable amount of $CaCO_3$ and EC. e.g. When the nitrogen content of the soil samples was examined, it was determined that the values were close to each other. While some micro elements were discovered to be over the limit levels, there was no physical evidence that these high concentrations were altering the metabolism of the plants included in the study. This situation can be considered as a potential indicator that these plants, which are scattered in nature, are genetically tolerant.

Keywords: Mineral nutrients, Chromium deposit, Sandras mountain, Wild plants.

Köyceğiz Özel Çevre Koruma Bölgesi'nde (Sandras Dağı) Yetişen Bazı Yabani Bitkilerin Besin İçerikleri

Öz

Bu çalışmada Sandras Dağı Gökçeova bölgesindeki Krom madeni çevresinde yaygın olarak yayılış gösteren bazı bitki türlerinin mineral içerikleri ile toprakların fiziksel ve kimyasal özellikleri araştırılmıştır. Toprak örneklerinde pH, $CaCO_3$, EC, kum, organik madde ve makro-mikro elementler açısından analiz edilirken, sürgün ve köklerde ise makro ve mikro element kapsamları belirlenmiştir. Toprak analizlerinden $CaCO_3$ ve EC seviyeleri uygun değerlerde olduğu gözlenmiştir. Ayrıca, toprak numunelerinin nitrojen içerikleri incelendiğinde değerlerin birbirine yakın olduğu tespit edilmiştir. Genel anlamda bazı mikro elementlerin sınır değerlerin üzerinde bulunmasına rağmen çalışmaya dâhil edilen bitkilerin bu yüksek değerlerden metabolik olarak etkilendiklerine dair fiziksel bir kanıt bulunamamıştır. Bu durum doğada dağınık olarak bulunan bu bitkilerin genetik olarak toleranslı olduğunun potansiyel bir göstergesi olarak değerlendirilebilmektedir.

Anahtar Kelimeler: Mineral besinler, Krom yatağı, Sandras dağı, Yabani bitkiler.

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1. Introduction

Turkey possesses a wide variety of vegetation types and a very rich floristic structure due to its geographical location, geomorphological structure, diverse soil types and the influence of different climatic characteristics. Muğla plays an important role in this diversity (Özhatay et al., 2005).

Sandras Mountain, part of the Köyceğiz district of Muğla, is located in southwest Anatolia, in the southwest of the Gölgeli Mountains parallel to the borders of the Aegean and Mediterranean regions. This mountain mass is bordered by the Namnam stream from the west, Dalaman stream and its branches from the east, Köyceğiz depression from the south and the Beyağaç (Eskere) depression from the north. Sandras mountain, which rises to 2294 meters (Çiçekbaba Hill) inside these boundaries, is one of the highest mountains in southwest Anatolia (Doğan, 2011). As a natural result of its geographical location, topography and wide climatic and geomorphological diversity, Sandras mountain is rich in habitat types and this is reflected in the number of plant species and the endemism rate. A large part of Sandras mountain and its near surroundings consists of serpentine rocks (Minerals in this group, which are rich in Magnesium and Silicon). Regions with serpentine bedrock are not very suitable for plant growth. However, certain plants (mostly endemic taxa) demonstrate very good growth and adaptation in such areas. This feature is defined as geological isolation. The fact that Sandras mountain possesses different vegetation series, ranges from 80 m to 2294 m in height and consists of mostly serpentine bedrock leads to high plant diversity, which also affects the endemism rate. According to the findings of the literature study, there is a tight association between endemism rate and rock structure (Anacker, 2014).

In the literature, there are many studies on the nutrient content, ecological adaptations, and distribution of endemic species of wild plants in various regions of Turkey (Yıldırım et al., 2001; Kibar & Temel, 2016; Güzelsoy et al., 2017). However, studies conducted in Muğla province, particularly in areas with high floristic richness such as Sandras Mountain, are quite limited. In this context, this study aims to fill a significant gap in the literature by providing new data on the nutrient contents, ecological requirements, and distribution maps of plant species specific to the region. Additionally, the study aims to provide deeper insights into the adaptation processes of endemic plants and their impacts on ecosystems, offering scientifically-based recommendations for the conservation of biological diversity.

As a result, this study not only makes important contributions to academic literature but also provides valuable data for nature conservation and ecosystem management.

2. Materials and Methods

The locations of the plants were identified by preliminary assessments of the Flora of Turkey book (Davis, 1965-1988), and the review of previous flora studies conducted within Muğla and other related sources. Table 1 lists the plant species studied in this study.

Table 1. Survey study at Ağla (Yayla) neighborhood.

Name of Species	Local name	Code name	Herbarium Number
Ebenus pisidica Hub.-Mor. & Reese	Dirmil Morgeveni	Ep	K.A. 1866-a
Genista anatolica Boiss.	Kandaş Dikeni	Ga	K.A. 1865-a
Thymus longicaulis subsp. *chaubardii* (Rchb.f.) Jalas	Dağ Kekiği	Tl	K.A. 1862-a
Asperula tenuifolia Boiss.	Sipil Belumu	At	K.A. 1864-a

The plant specimens were collected on June 2024 from open areas within *Pinus nigra* (Black Pine) forests in the vicinity of Gökçeova pond, located on Sandras mounth (Köyceğiz, Muğla). The plant identifications were performed by Kenan Akbaş. The herbarium numbers of the specimens are as follows: *Ebenus pisidica* Hub.-Mor. & Reese (K.A.1866-a), *Genista anatolica* Boiss. (K.A.1865-a), *Thymus longicaulis* subsp. *chaubardii* (Rchb.f.) Jalas (K.A.1862-a), and *Asperula tenuifolia* Boiss. (K.A.1864-a).

Some of the samples collected were appropriately pressed and left to dry to be identified, while the information specified for each plant species was noted and analyzed in the Biology Department Herbarium. Soil samples were collected for each plant species from the locations where the plants were harvested in addition to shoot and root samples from the 4 specified plant taxa. The soil and plant samples collected were subjected to pre-treatment in the laboratory.

2.1. Chemical and physical analysis

Soil samples were collected from five separate places to represent the field before being blended, transported to the laboratory, pre-treated, and prepared for analysis. $CaCO_3$ was determined calcimetrically, the amount of organic matter was determined using the method proposed by Walkley and Black (1934), available Zn, Fe, Mn and Cu that can be obtained from the soil samples was determined in accordance with the DTPA (diethylene-triamine-penta-acetic-acid) (Lindsay and Norvell, 1978) method while available K, Ca and Mg content (Thomas, 1982) and available Na content (Knudsen et al., 1982) were determined using the extracts obtained with 1 N neutral ammonium acetate solution through an atomic absorption spectrophotometer. Furthermore, the water-soluble phosphorus level was evaluated colorimetrically with a spectrophotometer using Bingham (1982). The B available for the plant in the soil was created based on the 0.01 M manitol+$CaCl_2$ extract method while the amount of B was determined using the ICP-AES (Kacar and Fox, 1966), and pH and EC were determined through a combined pH-EC meter. Total nitrogen determination in the soil samples was made by Kjeldahl method.

The plant samples were cleaned with tap water before being rinsed with huge amounts of pure water. The samples were then dried for 72 hours on a stove at 70 °C. The dried plant samples were crushed, and 1 g was extracted before decomposing in a muffle furnace at 550 °C for 6 hours. The ash obtained after the decomposition process was extracted with 2 N of warm HCl and pure water, and the macro elements P, K, Ca and Mg and the micro elements Fe, Cu, Mn, Zn and B contents were determined using the ICP-OES with separate wavelengths specific to each element Kacar (1992). The Kjeldahl method was used to determine total nitrogen in plant samples. The data were presented in the form of % and ppm in dry matter.

3. Findings and Discussion

3.1. Analysis results of soil samples

Table 2 shows the physical and chemical properties of soil samples gathered as a result of studies conducted in soils with naturally occurring plant species.

Table 2. Data on the analysis results of soil samples

Parameters		Ep	Ga	Tl	At
EC (dS/m)		0.57	0.35	0.36	0.87
pH		5.74	5.66	5.72	5.86
$CaCO_3$ (%)		0.33	0.15	0.31	0.15
Organic Matter (%)		2.35	1.55	1.94	2.13
Nitrogen (%)		0.12	0.08	0.10	0.11
Macro Elements (ppm)	Phosphorus (P)	13.00	6.00	11.00	4.00
	Potassium (K)	76.03	85.82	79.00	168.56
	Calcium (Ca)	1155	807	821	1711
	Magnesium (Mg)	925	361	380	666
	Sodium (Na)	15.32	19.15	58.99	31.15
Micro Elements (ppm)	Iron (Fe)	88.58	53.31	62.03	66.65
	Copper (Cu)	1.20	0.16	0.06	0.48
	Manganese (Mn)	151.58	115.81	131.88	111.42
	Zinc (Zn)	1.87	0.46	0.57	0.74
	Boron (B)	24.50	41.40	17.40	18.80

*Ep: Ebenus pisidica; Ga: Genista anatolica; Tl: Thymus longicaulis; At: Asperula tenuifolia

The pH of soil samples has a considerable impact on metal extraction (Ettler et al., 2007). pH of the soils is usually mildly acidic, averaging 5.75. When the soil qualities of the locations were investigated in general, research revealed that loamy soils with low pH, salt (EC), and $CaCO_3$ concentration are preferable. In the study conducted by Allison and Moodie (1965) on $CaCO_3$ content in soils, the proposed range of values was reported as 5.1–15.0%. Based on this range of values, it was determined that all of the soils examined had very low $CaCO_3$ content. Moreover, the soils belonging to the species had the lowest organic matter content in the species *Genista anatolica* with 1.55% and the highest in the species *Ebenus pisidica* with 2.35% (Table 2). In the study conducted by Walkley and Black (1934) it was reported that the range of organic matter values in soils should be between 2.01% and 3.0%. Based on this, it was determined that approximately 25% of the sampled soils contained low organic matter and 75% contained sufficient organic matter. It was determined that the EC values of the soil samples taken from the study site ranged between 0.35 and 0.87 dS/m (Table 2). In the study conducted by Waters et al. (1972), the proposed range of EC values was reported as 1.51-2.25 dS/m. Compared with these values, it was revealed through analyses that the soils tested were within the 100% salt-free class and that there was no problem in relation to salinity or total soluble salt concentration in water.

In terms of total nitrogen content, the soil sample of the *Genista anatolica* species had the lowest value (0.08%), whereas the soil sample of the *Ebenus pisidica* species had the highest (0.12%) (Table 2). In the study conducted by FAO (1990), the proposed N limit values for the soils were reported as 0.15-0.40%. Accordingly, almost all of the soils examined in this study were found to be low in nitrogen level.

In terms of other soil macro element levels in general, it was established that the plant-available phosphorus (P) value was between 4.00 and 13.00 ppm (Table 2). Olsen et al. (1954) indicated that P limit values should be between 7.1 and 25 ppm in their investigation. In this case, it was determined that 50% of the soil samples had low levels of phosphorus content while the phosphorus % contents of the other soil samples were at sufficient levels. Phosphorus deficiency may not always be related to the lack of plant-available phosphorus in the soil. In general, P deficiency in plants is significantly affected by various soil properties such as pH, temperature, humidity and the type and amount of other nutrient elements. Therefore, symptoms of P deficiency may sometimes be observed even in plants grown in soils with sufficient levels of phosphorus for normal plant growth (Kacar and Katkat, 2007).

The plant-available potassium (K) content of the soil samples was found to be within the range of 76.03-168.56 ppm. Anonymous (1980) reported the desired limit values in soil as 201-250 ppm. However, it was reported that all of the soil samples had low levels of K. In soils, plant-available potassium constitutes a very small part of the overall potassium. It is acknowledged that a large part of the total potassium in soil is not available to plants (Kacar and Katkat, 1998). The highest plant-available calcium (Ca) content was determined as 1711 ppm while the lowest was found to be 807 ppm. Anonymous (1980) stated that the intended limit values for soil were 1439-3862 ppm. However, it was found that most of the soil samples had low levels of Ca. Calcium, an essential mineral for plant growth and development, plays a critical role in cell growth and development, membrane permeability adjustment, and supplying plants with quality-related characteristics (Marschner, 1995). According to Anonymous (1980), Mg limit values were determined to be between 116-475 ppm, and when the Mg concentration in our soil samples was evaluated, half of it was found to be sufficient, while the other half was found to be high. This may result from the interaction between the elements and seasonal differences. Various literature evaluations found that the most notable interactions occur between K, Ca, and Mg, and that an excess of one of these elements in a plant can lead to a lack of another (Kacar, 1995).

Despite the fact that micro elements are mineral components that have a wide range of biochemical roles in living organisms and are essential for human health, large amounts can be hazardous (Gürel, 2014). The recommended sufficient values of the micro elements in the soils examined were reported as Cu (0.2 ppm), Mn (1 ppm), Fe (2-4.5 ppm), Zn (0.5-1.0 ppm) (Follett and

Lindsay, 1970) and B (0.5-1.0 ppm) (Bray, 1948). When the micro element contents of the soils are evaluated based on the reference ranges, it was determined that the Fe and B contents are very high while the Mn and Zn values are at suitable or low levels. In terms of the Cu content of the soils, it was found that approximately 75% of the soils had suitable or low levels of Cu while 25% had high levels (Table 2).

3.2. Analysis results of plant samples

Table 3 shows the macro-micro element contents of the shoot and root parts based on the plant species.

Table 3. Macro and micro element contents of the shoot and root parts of the species

Parameters		Plant parts	Ep	Ga	Tl	At
Macro Elements (%)	Nitrogen (N)	Shoot	2.83	2.68	2.75	2.00
		Root	1.63	1.97	2.29	1.66
	Phosphorus (P)	Shoot	0.35	0.40	0.18	0.18
		Root	0.12	0.11	0.19	0.16
	Potassium (K)	Shoot	0.84	1.52	0.69	1.93
		Root	0.27	0.65	0.32	0.99
	Calcium (Ca)	Shoot	1.46	0.86	0.28	1.16
		Root	1.09	0.98	0.36	0.63
	Magnesium (Mg)	Shoot	0.50	0.59	0.37	0.32
		Root	0.25	0.71	0.28	0.37
Micro Elements (ppm)	Iron (Fe)	Shoot	3541	2580	4099	2839
		Root	2734	4335	4150	4821
	Manganese (Mn)	Shoot	427	67	96	242
		Root	247	112	323	310
	Zinc (Zn)	Shoot	20.03	31.88	75.68	57.10
		Root	13.19	34.43	35.32	38.11
	Copper (Cu)	Shoot	5.60	14.33	3.88	17.72
		Root	7.43	16.18	10.75	11.26
	Boron (B)	Shoot	34.36	28.23	10.64	22.63
		Root	13.73	33.89	10.35	10.72

*Ep: Ebenus pisidica; Ga: Genista anatolica; Tl: Thymus longicaulis; At: Asperula tenuifolia

When the plant shoot nitrogen content in Table 3 is showed, it is observed that the highest value is in the *Ebenus pisidica* shoots with 2.83% while the lowest value is in the *Asperula tenuifolia* shoots with 2.00%. When the average Nitrogen (N) content of the plant roots was examined, it was found to be 1.89% (Table 3). Korkmaz et al. (2014) reported that the nitrogen contents of certain medicinal and aromatic plants (*Laurus nobilis* L., *Matricaria chamomilla* L., *Urtica diocica* L., *Achillea millefolium* L., *Hypericum perforatum* L. and *Tilia cordata* L.) varied between 1.41% and 3.78%. In another study, the nitrogen content of 29 medicinal and aromatic plants widely consumed in Greece was reported to vary between 0.14% and 3.24% (Karagiannidis et al., 2010). The literature findings support the nitrogen contents obtained in the present study.

The shoot P content determined in the present study varies between 0.18-0.40% while the root P content varies between 0.11% and 0.19% (Table 3). There are studies on the subject in the literature. For example, the phosphorus content of medicinal and aromatic plant samples (papaya, lime flower, nettle, St. John's wort, laurel, and yarrow) obtained from spice shops in certain provinces in Northern Turkey was found to range between 0.11% and 0.54% (Korkmaz et al., 2014) while this value was reported to vary between 0.07% and 0.34% in certain *Lamiaceae* family members (thyme, rosemary, lavender, sage, basil, and oregano) (Kara et al., 2014). When the P contents identified in the present study are examined, it is observed that they are in line with the aforementioned literature findings.

The average amount of potassium in the shoots and roots of the plants analyzed was found to be 1.25% and 0.56%, respectively (Table 3). Looking at the literature, it was reported that the amount of potassium in *Malva sylvestris* L., *Cichorium intybus* L., Asparagus acutifolius L., *Chenopodium album* L., *Foeniculum vulgare* Mill., *Papaver rhoeas* L. and *Polygonum aviculare* L., which are consumed as vegetables in the Aegean Region, varied between 0.29-0.58 mg/100g (Kaya et al., 2004). In another study, it was found that the potassium content of the wild plants (*Arum dioscoridis* L., *Chenopodium album* L., *Malva sylvestris* L., *Mentha longifolia* (L.) L., *Nasturtium officinale* R.Br., *Papaver rhoeas* L., *Polygonum aviculare* L., *Rumex acetosella* L., *Sinapis alba* L. and *Urtica dioica* L.) in the Kilis and Gaziantep regions mainly varied between 2.5-3% (Akgünlü, 2012). There are similar and/or contradictory findings between the data obtained in the present study and the aforementioned studies in the literature.

In our study, the highest Ca content among the shoot and root parts of the plant species included in the present study was found in *Ebenus pisidica* (Table 3). In another study conducted, the calcium content of the *Gentiana olivieri* Griseb. plant was found to be 0.33% at the lowest and 1.76% at the highest in the stems of the plant (Koca et al., 2008). In another study, it was observed that the calcium content of the *Arnebia densiflora* (Nordm.) Ledeb. plant varied between 0.92 and 3.76% in different parts of the plant (Koca et al., 2009).

In this study, the magnesium (Mg) contents determined in the shoots and roots of the examined plant species showed significant differences between species. Notably, *Genista anatolica* had the highest Mg content, measured at 0.59% in shoots and 0.71% in roots. In contrast, the lowest Mg contents were recorded in *Asperula tenuifolia* (0.32%) and *Ebenus pisidica* (0.25%). These results reveal the influence of species-specific physiological traits on mineral accumulation. In a similar study reported in the literature, the mineral nutrient contents of certain aromatic plants grown in the Muğla region were analyzed, and the lowest Mg content was found in *Cichorium intybus* (0.18%), while the highest was recorded in *Brassica oleracea* var. *capitata* (0.58%) (Atabey et al., 2020). In both studies, it was observed that Mg accumulation varies considerably among different species, which is associated not only with the plants' genetic makeup but also with environmental factors such as soil structure, pH, organic matter content, and climatic conditions.

When we look at the microelement contents of plant samples in our study, the average iron contents of the shoot and root parts of the plants analyzed were determined as 3265 and 4010 ppm, respectively. The highest Fe content was detected in the shoot of the *Thymus longicaulis* plant with 4099 ppm (0.41%) (Table 3). Generally, the trace amount of iron that plants can contain is 50-250 ppm. In our study, considering the limit values, it was observed that the Fe content in the shoots and roots of all the plants examined was well above the recommended values. In the study conducted by Turan (2014), the heavy metal and mineral nutrient element contents in the shoots and stems of certain medicinal plants and the iron contents measured in *Symphytum officinale* L. (849 ppm), *Viscum album* L. (728 ppm), *Salvia officinalis* L. (549 ppm), *Plantago lanceolata* L. (448 ppm), *Alkanna tinctoria* Tausch (358 ppm), *Artemisia dracunculus* Ledeb (318 ppm), *Ruta graveolens* L. (306 ppm) and *Taraxacum officinale* Cass (242 ppm) are in parallel with the results of the present study.

When the Mn contents of the species included in the present study are examined, the highest value is observed in the shoot part of *Ebenus pisidica* (427 ppm) while the lowest value was found in the shoot part of *Genista anatolica* (67 ppm) (Table 3). In one study, Meraler (2010) reported that the manganese content of the *Prunus mahaleb* varied based on the parts examined. The highest Mn content was found in the shoots of the *Prunus mahaleb* (36 ppm) while the lowest value (8 ppm) was found in the resin part. As a result of a previous study on certain plants that are grown naturally and consumed as vegetables in Ordu and its surroundings, it was reported that the manganese content of the plants ranged between 21.40 and 77.40 ppm (Şekeroğlu et al., 2005).

The average zinc content of the shoot and root parts of the plants was determined as 46.17 ppm and 30.26 ppm, respectively. The highest value was observed in the shoot part of *Thymus longicaulis* with 75.68 ppm (Table 3). In a previous study examining certain biological and ecological properties of Origanum (Lamiaceae) species endemic to Antalya, the annual average zinc content of the shoots of Origanum species; O. *solymicum, O. husnucanbaseri, O. bilgeri* and *O. minutiflorum* was reported as 14.5 ppm, 31.75 ppm, 38.75 ppm and 32.75 ppm, respectively (Ünal, 2003). As a result of the study, it was seen that the zinc contents of plants except *Ebenus pisidica* were compatible with the literature.

The highest Cu content in the shoot and root parts of the plants was found in *Asperula tenuifolia* (17.72 ppm) and Genista anatolica (16.80 ppm), respectively, while the lowest was found in *Thymus longicaulis* (3.88 ppm) and *Ebenus pisidica* (7.43 ppm) (Table 3). In a previous study, examining 30 medicinal plants in Kayseri (Tokatlıoğlu, 2012), it was reported that there was a very wide variation between 3.32 (*Ziziphus zizyphus* (L.) Meikle.) and 30.2 µg/g (*Ocimum basilicum* L.) in terms of copper content. A similar result was obtained by Şekeroğlu et al. (2006) for the copper content of wild plants (*Trachystemon orientalis* (L.) G.Don, *Smilax excelsa* L., *Ornithogalum umbellatum* L., *Amaranthus retroflexus* L., *Aegopodium podagraria* L. and *Urtica diocia* L.) consumed as vegetables in Ordu, and the copper contents were reported to range between 2.7 and 21.3 ppm. As a result of the study, it was seen that the copper contents of the plants were at similar values to the literature.

Boron is an element that is required by plants in trace amounts, and its deficiency and toxicity limits are very close to each other (Brown et al., 2002). When the B content of the plant species included in the present study are examined, it is observed that the highest value is found in the shoot part of Genista anatolica (34.36 ppm) while the lowest value is detected in the root part of *Thymus longicaulis* (10.35 ppm) (Table 3). In one study, the highest average boron contents in the stem/rhizome plants examined were observed in Verbascum sp. (13.156 ppm), *Valeriana officinalis* L. (11.2 ppm) and Arcticum lappa L. (7.9 ppm) while the lowest values were found in *Alpinia officinarum* Hance (0.95 ppm), *Curcuma longa* L. (0.7 ppm) and *Zingiber officinale* Roscoe (0.6 ppm) (Çolak, 2014).

4. Conclusions and Recommendations

In general, this study has provided important preliminary findings regarding the nutritional status of naturally occurring plant species distributed across the Sandras Mountain region. Although the nutritional element profiles (especially micro and trace elements) of the sampled plants have been revealed, it is evident that further detailed biochemical and toxicological analyses are required. In particular, the detection of certain microelements at concentrations above internationally accepted threshold values in some edible and medicinal plants raises critical concerns both for ecological health and potential human consumption.

Interestingly, despite the elevated concentrations of these elements, no visible signs of physiological or morphological stress were observed in the sampled plants. This may suggest that these species possess inherent tolerance mechanisms or are genetically adapted to the metal-rich edaphic conditions of the serpentine-dominated landscapes, possibly via enhanced antioxidant capacity or selective ion sequestration. Similar findings have been reported in serpentine-endemic taxa, which often exhibit metallophyte characteristics (Anacker, 2014; Rajakaruna, 2004).

When the results of the current study are compared with similar studies conducted in metal-rich soils—such as those by Yıldırım et al. (2001), Kibar and Temel (2016), and Güzelsoy et al. (2017)—it becomes apparent that the elemental accumulation patterns observed in this region are consistent with previously reported data.

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Authors' Contributions

All authors contributed equally to the study.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

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