FIRST DOCUMENTATION OF PLANT SPECIES DIVERSITY IN KHARTOUM REFINERY, SUDAN

ALAMIN, S. A. H.[1*] – ELAWAD, A. A.[1] – BABIKER, I. E. A. A.[1] – ALI, O. M. M. A.[1]

[1] *Biodiversity and NAT Research, Environmental and Natural Resources and Desertification Research Institute, Al Khurtum, Sudan.*

**Corresponding author*
e-mail: elaminsalma7[at]gmail.com

(Received 18th August 2021; accepted 21st October 2021)

Abstract. This is the first record data of plant species diversity in the new ecosystem after the establishment of Khartoum Refinery (KRC), a new ecosystem was appeared due to processing, operation of oil refining. Khartoum Refinery (KRC) is located north of Khartoum State, Sudan. This work aim to assess the impact of treated water from KRC on plant diversity; twelve field trips were carried out to cover dry and wet seasons. Plant specimens were collected, pressed, dried, identified, mounted according to the standard methods and then incorporated in the herbarium. Scientific names were updated from the website of the international plant list version. Sixteen (16) plant species belonging to nine (9) families were recorded in Khartoum refinery. This study concludes that treated water has indeed effect the biodiversity since many plant species growing and dominating. The study recommended periodic monitoring of vegetation and soil in KRC to study the accumulative impact of treated water on soil properties and plant diversity.
Keywords: *oil refining, treated water, plant specimens, periodic monitoring, plant diversity*

Introduction

Biodiversity is a widely used term having no unified definition (El Tahir and Vishwanath, 2015). It is an issue which is defined globally by different authors. It is a short form for biological diversity which is to describe the total number, variety and variability of living organisms as well as the diversity of the ecosystem they are living in. In this definition, diversity can be assessed at three levels: Genetic variation which encompasses genetic variability among the populations and the individuals of the same species. Species variation this encompasses variability among species at plot or field levels. It is one of the important specifications of bio-societies that are measured in different ways. Ecosystem variation within an area, biome, or planet this encompasses diversity at a higher level of organization. At this level the indicator of diversity is species dominance (El Tahir and Vishwanath, 2015).

The concept of biodiversity is considered to be the integration of biological variability across the above mentioned three scales to the landscapes that they form, or are part of, and the ecological processes that support them .Generally, biodiversity measurement focuses on the species level and species diversity is one of the most important indices which are used for the evaluation of ecosystems at different scales (Wilson, 1988). Problem statement**s** there are different residues that remain after produced water treatment which include oil, free metal and other toxic components of treated produced water. When these toxic components accumulate in the soil they can change soil chemical and physical properties which directly affect plant growth and composition. Objective of this research is to determine the member of plant species component of the new ecosystem diversity in Khartoum refinery.

Materials and Methods

Study area of Khartoum refinery

The study area landscape is located in the semi desert zone north of Khartoum State (*Figure 1*), at latitude range between 16.4023N to 16.1157N, as well as longitude range between 32.4609E to 32.2086E. According to Andrews (1950), as well as Harrison and Jackson (1958), the area is the semi desert grassland on sand in places with a thin scatter of *Acacia raddiana*, *A. mellifera* and *Commiphora* spp. The rainy season begins in July the end of September. The dry season begins in December and last June. The rainfall is about 164 mm per year. The annual minimum temperature average is 29.6ºC and maximum is 38ºC.

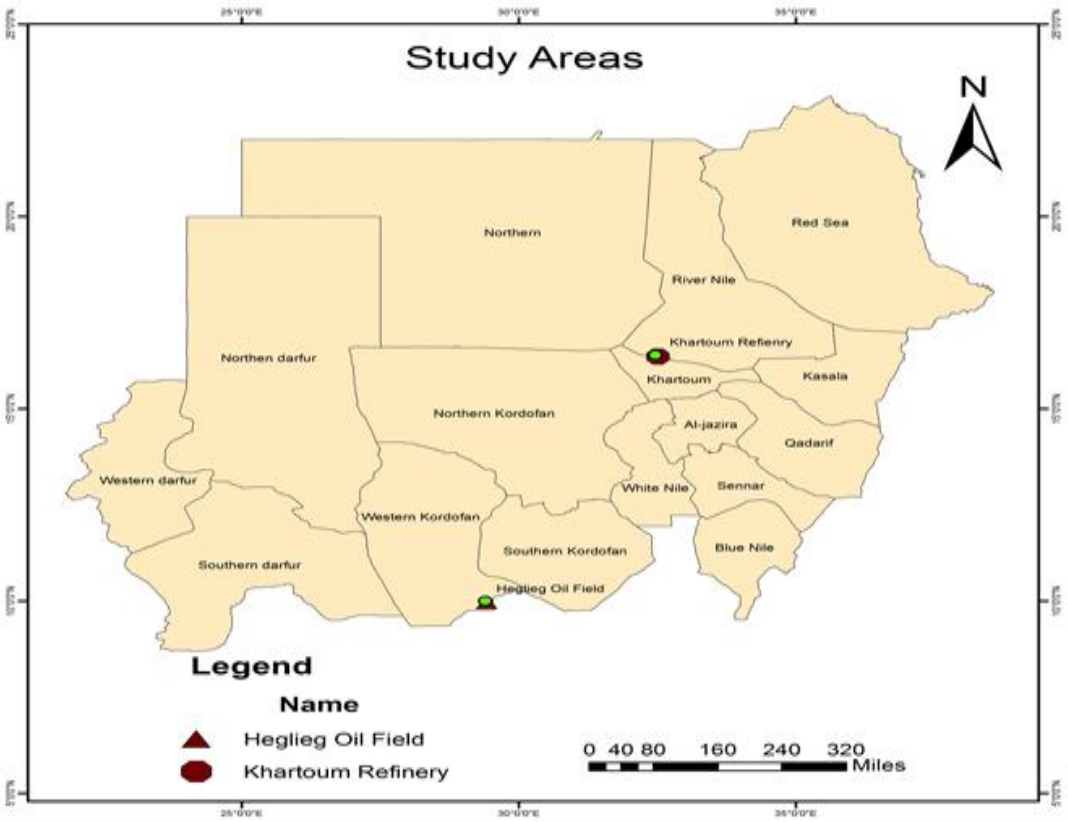

Figure 1. *The study area of Khartoum Refinery.*

Natural vegetation

According to White (1984), the area is located in the zone of Sahel semi-desert grassland transition to Sahara and grassland is the prevalent vegetation on deep sandy soils. It usually contains mixture of bushes and small bushy trees, the density of which is partly determined by local conditions. The woody species are *Acacia tortilis, Comiphora Africana , Balanites aegyptiaca, Boscia senegalenisis and Tamarix* sp on the wet areas. The desert grass land is dominated by *Aristida adscensionis* and *Panicum turgidum*.

Soil

The soil type is loam and sand dry (moist plus darker) sandy clay loam with very few small and large rock fragments. The structure is less except for the surface 2 cm clear wavy boundary, and the pH is 7.2.

Khartoum refinery treated waste water system

Physical oil removal: this concerns all mechanical processes which do not use any reagent. Physical-chemical oil removal is done by adding chemical reagents and biological treatment (alge and fungi) finally the treated water is fed into large forest area.

Sample collection

Direct observations and primary surveying were used to assess environmental conditions and plant community type. Plant specimens were collected from different sites of the study area at different times of the year in 2016. Collection procedure followed the methods described. The whole plant was collected in case of herbs and twigs with leaves and flowers and /or fruits in case of shrubs and trees. The sample size is all the plant in the study area was collected.

Preparation of specimens

The specimens collected were stretched to dry between newspapers and firmly pressed inside a herbarium press. Newspapers were continuously changed during drying to avoid rottening of material. Specimens were identified and verified using keys in the taxonomic references, namely: Broun and Massey (1929), Andrews (1956; 1952; 1950) and El Amin (1990). The specimens were mounted, labeled and deposited at the herbarium of the Environmental and Natural Resources and Desertification Research Institute (ENRDRI), National Centre for Research (NCR), Khartoum. Field observations were recorded including, habit, habitat, distribution and colors of flowers during the collection trips. In the herbarium further classification analysis and /or identification were carried out initially by examining the various parts of the specimens collected using a hand-lens. Fine floral characters were examined under Mbc-10 dissection microscope. Preliminary species identification was carried out using a set of keys (Andrews, 1956; 1952; 1950), Hutchinson et al. (1963), and Braun et al. (1991). Specimens were matched with identified and authenticated herbarium specimens in the herbarium of ENRDRI and the Herbarium catalogue of the Kew Royal Botanic Gardens (2021) for confirmation. The synonyms of the identified species were extracted from many references such as Hutchinson et al. (1963), Cronquist (1965), Wickens (1976), Sahni (1968), El Awad (1995), Elghazali (1985) and El Amin (1990).

Updating of plant names was taken into account according to recent literature namely: The Plant List (2021) and Kew Royal Botanic Gardens (2021). The list of clades and orders covered in this study was arranged according to APG (2008) and the families were arranged according to the Haston et al. (2009) while subfamilies, genera and species are arranged alphabetically. The vernacular names of species were recorded from local inhabitants within the study area and also extracted from Broun and Massey (1929) as well as Andrews and Tothill (1948), for citation of species only the oldest reference cited was (Sp. Pl. in most cases), in addition to Andrews (1956; 1952; 1950). Economic uses given were compiled from local people and available literature. The life-forms of plants were formulated according to Raunkiaer (1934).

The abbreviations

The abbreviations can be includes: (1) C=Central Sudan; (2) D=Darfur; (3) Es=Eastern Sudan; (4) Kh=Khartoum State; (5) Kd=Kordofan; (6) KRC=Khartoum Refinery; and (7) N=Northern Sudan.

Results and Discussion

The results showed that the flora of Khartoum refinery is composed of 16 species which belong to 9 families (*Table 1*). Updated classification of these;

Table 1. *Plant species of Khartoum Refinery.*

No.	Fanily	Scientific name
1	Amaranthaceae	*Aerva javanica* (Burm.F.) Juss . ex Schult
2	Apocynaceae	*Calotropis procera* (Aiton)
3	Compositae	*Aaronsohnia pubescens* (Desf.) K. Bremer &Humphries
4	Cucurbitaceae	*Cirtullus coloynthis* (L.) Schrd
5	Leguminosea	*Acacia seyal* Delile
6	Leguminosea	*Acacia tortillis* (Forsk.) Hayne.Sp *spirocarpa* Hochst. Ex A. Rich
7	Leguminosea	*Rhynchosia memnonia* (Del.) DC
8	Leguminosea	*Tephrosia uniflora* Pers
9	Leguminosea	*Senna alexandrina* Mill
10	Malvaceae	*Crochours depressus* (L.) Stocks
11	Poaceae	*Aristida adscensionis* L
12	Poaceae	*Chloris virgata* Sw
13	Poaceae	*Panicum turigdum* Forsk
14	Tamaricaceae	*Tamarix senegalensis* DC
15	Zygophyllaceae	*Fagonia cretica* L
16	Zygophyllaceae	*Seetzenia orientalis* Decne

Clade: Monocots/Commelinids
Order: Poales
Family: Poaceae. Subf. Arundinoideae
Scientific name: ***Aristida adscensionis*** L. (*Figure 2*), Sp. Pl.:82 (1753);
Andrews, Flowering plants of the Sudan,VolIII: 395 (1956).
Synonym: *A.abyssinica* Tin & Rupr.,Sp. Gram. Stipac. 1:34 (1842).
Local name: Gao
Uses: Fodder.
Distribution: C, D, Es, Kd, Kh, N

Figure 2. *Aristida adscensionis.*

Family: Poaceae. Subf.Chloridoideae
Scientific name: ***Chloris virgata*** Sw. (*Figure 3*), Fl. Ind. Occid. 1: 203 (1797), Andrews; Flowering plants of the Sudan,VolIII: 418 (1956).
Synonym: *Chloris alba* J.Pres, L.Reliq. Haenk.1: 289 (1830).
*Agrostomia barbata*Cerv., Naturaleza (Madrid) 1870: 346 (1870).
Local name: Afn
Life form: Therophytes
Uses: Fodder.
Distribution: C, D, Es, Kd, Kh, N**.**

Figure 3. *Chloris virgata Sw.*

Family: Poaceae. Subf.Panicoideae
Scientific name: ***Panicum turgidum*** Forssk. (*Figure 4*), Fl. Aegypt.-Arab. 18 (1775); Andrews, Flowering plants of the Sudan,VolIII: 504 (1956).

Synonym: Panicum *frutescens*Mez,Bot. Jahrb. Syst. 57*:* 186 (1921).
Local name: Tomam
Distribution: C, D, Kh.
Life form: Therophytes
Uses: Fodder and medicinal

Figure 4. *Panicum turgidum Forssk.*

Clade: Eudicots/Eurosids I
Order :*Zygophyllales*
Family: Zygophyllaceae. Subf. Seetzenioideae
Scientific name: ***Seetzenia lantana*** (Wild) Bullock. (Figure 5), Kew Bull. 19: 204 (1965).
Synonym: *Zygophyllum lanatum* Willd.,Sp. Pl. 2. 2(1): 564. (1799).
*Seetzenia orientalis*Decne.,Ann. Sci. Nat., Bot. II, 3: 281 (1835);
Andrews, Flowering plants of Anglo-Egyptian Sudan Vol I: 124 (1950).
Local name: Hyben
Life form: Therophytes
Distribution: C., D., Kh.
Uses: Fodder and medicinal

Figure 5. *Seetzenia lantana(Wild) Bullock.*

Family: Zygophyllaceae. Subf. Zygophylloideae
Scientific name: ***Fagonia cretica*** L.,Sp. (*Figure 6*) Pl. 386 (1753);
Andrews, Flowering plants of Anglo-Egyptian Sudan,VolI: 124(1950).
Synonym: *Fagonia deflexa*Moench, Suppl. Meth.: 82 (1802).
Local name: Um shoeka
Distribution: C, D, Kh.
Life form: Chamaephytes
Uses: Fodder and medicinal

Figure 6. *Fagonia cretica L.*

Order: *Fabales*
Family: Fabaceae (Leguminosae). Subf: Caesalpinoideae (syn. Caesalpinaceae)
Scientific name: ***Senna alexandrina*** Mill. (*Figure 7*), in Lock, Kew Bull.43: (1988);

Synonym: *Cassia senna* L., Sp. Pl.: 377(1753);Andrews, Flowering plants of the Anglo-Egyptian Sudan Vol II: 118(1952). *C. lanceolata* Forssk., Fl. Aegypt.-Arab.:85 (1775). *C. acutifolia* Delile.,Fl. Aegypte: 219(1813).
Local name: Sana, Sanya, Sanamaka.
Life form: Chamaephytes.
Uses: Medicinal used in the form of senna pods, or as herbal tea made from the leaves, as a laxative. Fodder.
Distribution: C, D, Es, Kd, Kh, N

Figure 7. *Senna alexandrina Mill.*

Family: Fabaceae (Leguminosae). Subf.: Mimosoideae (syn. Mimoaceae)
Scientific name: ***Acacia seyal*** Delile (*Figure 8*), Fl. Aegypte: 286 (1813); Andrews, Flowering plants of the Anglo-Egyptian Sudan Vol II: 144 (1952).
Synonym: *Acacia fistua* Schwenif.,Linnaea 35: 344. (1867)**.**
Local name: Talih
Life form: Phanerophytes
Uses: An important source for gum (talha gum) and wood.Fodder and medicinal.
Distribution: C, D, Es, Kd, Kh, N

Figure 8. *Acacia seyal Delile.*

Scientific name: ***Acacia tortilis*** **subsp.** ***spirocarpa*** (A.Rich.) (*Figure 9*)
Brenan, Kew Bull.1957:88(1957).
Synonym: *A. Spirocarpa* Hochst. ex A. Rich., Tent. Fl. Abyss. 1:239(1847). *Acacia tortilis* (Forssk.) Hayne, in Andrews, Flowering plants of the Anglo-Egyptian Sudan Vol II:142(1952).
Local name: Sumer
Life form: Phanerophytes
Uses: Fodder, medicinal and charcoal.
Distribution: N, C

Figure 9. *Acacia tortilis subsp. spirocarpa (A. Rich.) Brenan.*

Family: Fabaceae (Leguminosae). Subf.: Paplionoideae (syn. Paplionaceae)
Scientific name: ***Rhynchosia minima*** **var.** ***memnonia*** (Delile) (*Figure 10*) T.Cooke. In Tackholm, St.F.E.:284, Pl.89 (1974).

Synonym**:** *Glycine memnonia* Delile, Descr. Égypte, Hist. Nat. (1813)
Rhynchosia memnonia (Delile) DC.,Prodr.2:386 (1825); Andrews, Flowering plants of the Anglo-Egyptian Sudan Vol II: 228 (1952).
Local name: Adanelfar, Adna.
Life form: Chamaephytes.
Uses: Fodder and medicinal.
Distribution: Widespread

Figure 10. *Rhynchosia minima var. memnonia (Delile) T.Cooke.*

Scientific name: ***Tephrosia uniflora*** Pers., Syn. Pl. [Persoon] 2(2): 329. (1807); Andrews, Flowering plants of the Anglo-Egyptian Sudan Vol II: 236 (1952).
Synonym:*Tephrosia quartiniana* Cufod., Bull. Jard. Bot. État Bruxelles 25(Suppl.): 283 (1955). *Tephrosia transjubensis* Chiov.,Fl. Somala 2: 161 (1932).
Tephrosia vicioides A.Rich.,Tent. Fl. Abyss. 1: 188 (1847).
Local name:Hemera
Life form :Chamaephytes.
Uses: Fodder

Figure 11. *Tephrosia uniflora Pers.*

Clade: Eurosids I
order: *Cucurbitales*
Family: Cucurbitaceae. Subf.Cucurbitoideae
Scientific name: ***Citrullus colocynthis*** (L.) Schrad., Linnaea 12: 414 (1838)**.**
Synonym**:** ***Colocynthis*** *vulgaris* Schrad.(*Figure 12*), Index Seminum (GOET) 1833: 2 (1833); Andrews, Flowering plants of the Anglo-Egyptian SudanVol I: 166 (1950).*Cucumis colocynthis* L.,Sp. Pl. 1011 (1753).
Local name: Handel
Life form: Therophytes.
Uses: Medicinal.
Distribution: C, D, Es, Kd, Kh, N

Figure 12. *Cirtulluscoloynthis (L.) Schrad.*

Clade: Eurosids II

Order: *Malvales*
Family: Malvaceae. Subf. Grewioideae
Scientific name: ***Corchorus depressus*** (L.) Stocks (*Figure 13*), Proc. Linn. Soc. London 1:367 (1848)**.**
Synonym: *Antichorus depressus* L.,Mant.Pl. 1: 64 (1767).*Corchorus depressus* (L.) C. Chr.,Dansk Bot. Ark. 4(3): 34 (1922)*;* Andrews, Flowering plants of the Anglo-Egyptian SudanVol I: 217 (1950).
Local name: Um takasho
Life form: Therophytes.
Uses: Fodder, food and medicinal.
Distribution: C, D, Es, Kd, Kh, N

Figure 13. *Corchorus depressus (L.) Stocks.*

Clade: Eurosids I
Order: *Caryophyllales*
Family: Tamaricaceae
Scientific name**:** ***Tamarix senegalensis*** DC. (*Figure 14*), Prodr. 3: 96 (1828).
Synonym: *Tamarix nilotica* **(**Ehrenb.) Bunge, Tent. Gen. Tamar. 54 (1852); Andrews, Flowering plants of the Anglo-Egyptian SudanVol I: 161 (1950).*Tamarix arabica* Bunge, Tent. Gen. Tamar. 55 1852.
Local name: Tarffa.
Uses: Medicinal.
Life form: Phanerophytes
Distribution: C, D, Es, Kd, Kh, N

Figure 14. *Tamarix senegalensis DC.*

Clade: Eurosids I
Order: *Caryophyllales*
Family: Amaranthaceae. Subf.Amaranthoideae
Scientificname: ***Aerva javanica*** (Burm. f.) Juss.exSchult. (*Figure 15*), Ann. Mus. Hist. Nat.11: 131 (1808); Andrews, Flowering plants of the Anglo-Egyptain SudanVol I: 113 (1950).
Synonym: *Achyranthes alopecuroides* Lam.,Encycl. 1: 548 (1785).
Local name: Raselshayib
Life form: Chameaphytes.
Uses: Fodder and medicinal.
Distribution: C, D, Es, Kd, Kh, N

Figure 15. *Aerva javanica (Burm. f.) Juss.exSchult.*

Clade: Euasterids I

Order: Gentianales
Family: Apocynaceae. Subf.Asclepiadoideae
Scientific name: ***Calotropis procera*** (Aiton) Hortus (*Figure 16*), Kew. 2: 78 (1811); Andrews, Flowering plants of the Anglo-Egyptain SudanVol II: 402 (1952).
Synonym: *Asclepias procera* Ait., Hort.Kew.I:305(1789).
Local name: Usher
Life form: Nanophanerophytes.
Uses: Medicinal, Fodder.
Distribution: C, D, Es, Kd, Kh, N

Figure 16. *Calotropis procera (Aiton) Hortus.*

Clade: Euasterids II
Order: *Asterales*
Family: Asteraceae
Scientific name: ***Aaronsohnia pubescens*** (Desf.) K. Bremer &Humphries (*Figure 17*), Bull. Nat. Hist. Mus. London, Bot. 23(2):157 (1993).
Synonym: *Cotula pubescens* Desf.Fl. Atlant. 2: 284 (1799). *Chamomilla pubescens* (Desf) Alavi., Fl. Libya 107: 150 (1983)**.**
Local name: Sefera
Life form: Therophytes.
Uses: Medicinal.
Distribution: C, Kh, N

Figure 17. *Aaronsohnia pubescens (Desf.) K. Bremer &Humphries.*

Conclusion

This study concludes that treated water has indeed effect the plant diversity since many plant species are growing and dominating. This 16 species are the first members' components of the new ecosystem. The study recommended periodic monitoring of vegetation and soil in KRC to study the accumulative impact of treated water on soil properties and plant diversity.

Acknowledgement

The research study is self-funded.

Conflict of interest

The authors declare that there is no conflict of interest for this article.

REFERENCES

[1] Andrews, F.W. (1956): The flowering plants of the Anglo-Egyptian Sudan. – The flowering plants of the Anglo-Egyptian Sudan 3: 579p.
[2] Andrews, F.W. (1952): The flowering plants of the Anglo-Egyptian Sudan. – The flowering plants of the Anglo-Egyptian Sudan 2: 491p.
[3] Andrews, F.W. (1950): The flowering plants of the Anglo-Egyptian Sudan. – The flowering plants of the Anglo-Egyptian Sudan 1: 237p.
[4] Andrews, F.W., Tothill, J.D. (1948): Agriculture in the Sudan. – Oxford University Press 29p.
[5] Angiosperm Phylogeny Group (APG) (2008): An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. – Botanical Journal of the Linnean Society 161(2): 105-121.
[6] Braun, M., Burgstaller, H., Hamdoun, A.M., Walter, H. (1991): Common weeds of central Sudan. – Verlag Josef Margraf 333p.

[7] Broun, A.F., Massey, R.E. (1929): Flora of the Sudan. – Sudan Government House 503p.
[8] Cronquist, A. (1965): The status of the general system of classification of flowering plants. – Annals of the Missouri Botanical Garden 52(3): 281-303.
[9] Elghazali, G.E.B. (1985): The flora of the eastern Nuba Mountains with special reference to medicinal plants. – Khartoum: University of Khartoum 275p.
[10] El Awad, A.A. (1995): Ecotaxonomical studies on vegetation of Red Sea State, Sudan. – University of Khartoum 100p.
[11] El Amin, H.M. (1990): Trees and shrubs of the Sudan. – Ithaca Press 491p.
[12] El Tahir, B.A., Vishwanath, A. (2015): Market and value chain analyses of marketable natural products from agroforestry systems in Eastern Sudan. – Journal of Geoscience and Environment Protection 3(09): 57-73.
[13] Harrison, M.N., Jackson, J.K. (1958): Ecological classification of the vegetation of the Sudan. – Ecological classification of the vegetation of the Sudan 45p.
[14] Haston, E., Richardson, J.E., Stevens, P.F., Chase, M.W., Harris, D.J. (2009): The Linear Angiosperm Phylogeny Group (LAPG) III: a linear sequence of the families in APG III. – Botanical Journal of the Linnean Society 161(2): 128-131.
[15] Hutchinson, J., Dalziel, J.M., Hepper, F.N. (1963): Flora of West Tropical Africa. – Flora of West Tropical Africa 2: 544p.
[16] Kew Royal Botanic Garden (2021): The Kew Herbarium Catalogue. – Kew Royal Bortanic Gardens Official Portal. Available on:
https://apps.kew.org/herbcat/navigator.do
[17] Raunkiaer, C. (1934): The life-forms of plants and their bearing on geography. – Oxford University Press 102p.
[18] Sahni, K.C. (1968): Important trees of the Northern Sudan. – Khartoum University Press 138p.
[19] The Plant List (2021): A working list of all plant species. – The Plant List Official Portal. Available on:
http://www.theplantlist.org/
[20] White, F. (1984): The vegetation of Africa: a descriptive memoir to accompany the Unesco/AETFAT/UNSO vegetation map of Africa. – United Nations Educational 354p.
[21] Wickens. G.E. (1976): The Flora of Jebel Marra and its Geogrpahical Affinites. – Kew Royal Botanic Garden 368p.
[22] Wilson, E.O. (1988): The current state of biological diversity. – Biodiversity 521(1): 3-18.