The African Paleotropical floristic categories links to the Flora of highland plains in Yemen

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DOI: https://doi.org/10.47372/ujnas.2019.n1.a12

Abstract

About 222 plant species (two Ferns, one Gymnosperm, 219 Angiosperms: 169 Dicotyledons and 50 Monocotyledons) from the total 249 species were recorded from the Highland plains in Yemen, showing a distribution relationship with three African paleotropical floristic regions and 10 African paleotropical floristic elements. The distribution relationship among the African paleotropical floristic elements was subjected to numerical analysis: the African paleotropical floristic region with the highest number of species is Sudano-Zambezian, with 207 (83.1 %) species; while the African paleotropical floristic element, with the highest number of species, is the Afro-Montane Archipelago-Like Regional Centre of Endemism, with 184 (73.9 %) species.

Key words: African floristic elements, paleotropical, highland plains, Yemen, numerical analysis.

Introduction

Based on the physiography of Yemen; eight main vegetation land scope units have been identified: Coastal plains, Low altitude mountains, Medium altitude mountains, High altitude mountains, Highland plains, Eastern and northern east mountains, Eastern desert and Soqotra Archipelago (2); seven of them (Coastal plains, Low altitude mountains, Medium altitude mountains, High altitude mountains, Highland plains, Eastern and northern east mountains, Eastern desert) are represented in the western part of Yemen (2&34); while the large part of the eastern side of Yemen is represented by the Eastern desert (2). However, Highland plains of Yemen consist of a series of intermountain plains (45) most of them located in the Eastern and Northern east mountains (34). Moreover, Highland plains are divided into two elements according to elevation; High altitude plains located over 1800m asl and low altitude plains located lower than 1800m asl (2).

In this respect White (44) illustrated seven ecological regions in north and center Africa; while Zohary (49) classified Africa as a part of the Paleotropical kingdom except its northern part (Mediterranean region) that was classified as a part of the Holarctic Kingdom. In addition, he placed Yemen within the Eriterio-Arabian province which is a meeting point between the Sudanese region and Saharo-Arabian region.

Furthermore, White (45) renewed the classical phytogeographical definitions such as Kingdom, Regions, Provinces, Sections, Districts, etc. by establishing a new system based on the richness of endemic flora in such a region, thus he classified Africa into 18 Phytogeographical regions, including nine regional centres of endemism parted by six regional transitional zones and three regional mosaics. Following White's system (44), a chorological map covering southwest of Asia and a part of Africa has been obtained by Leonard (29&30).

Based on the previous studies, a phytogeographical map of Africa and southwest of Asia was modified by White & Leonard (45) where they classified the African Paleotropical Kingdom into 10 phytogeographical elements; namely: Sahara Regional Subzone (SS1); Sudanian Regional Centre of Endemism (S), Sahel Regional Transition Zone (Sa), Somalia-Masai Regional Centre of Endemism (SM), Afro-Montane Archipelago-Like Regional Centre of Endemism (Af), Zambezi Regional Centre of Endemism (Z) & Zanzibar-Inhambane Regional Mosaic (ZI); Guinea-Congolian Centre of Endemism (GC) Guinea-Congolian / Sudania Regional Transition Zone (GCS), and finally, Guinea-Congolian / Zambezia Regional Transition Zone (GCZ). Furthermore, they suggested that Yemen is a meeting point of two regional centres of endemism (Somalia-Masai Regional Centre of Endemism

Univ. Aden J. Nat. and Appl. Sc. Vol. 23 No.1 – April 2019 151
The African Paleotropical floristic ………Hassan Ibrahim, Hana Saleh, Abdul Nasser Al-Gifri

(SM) and Afro-Montane Archipelago-Like Regional Centre of Endemism) and one regional subzone (Arabian Region subzone).

Recently, Al Khulaidi (2) revealed that the flora of Yemen is a combination of Tropical African Sudanese plant region (west mountains and part of highland plains of Yemen) and Saharo-Arabian plant region (coastal plains, eastern mountains, eastern and northern east desert plains). He also mentioned that the Tropical African Sudanian plant region is highly presented in the flora of Yemen. On the other hand, about 249 plant species (three Ferns, one Gymnosperm, 56 Monocotyledoneae and 189 Dicotyledoneae) were recorded from the Highland plains in Yemen (1; 2; 3; 4 & 47).

The present study seeks to investigate the links between the African paleotropical floristic elements and the flora of highlands in Yemen.

Material and methods

The Phytogeographical relationship between the African paleotropical floristic elements and the flora of highland in Yemen was investigated by studying the distribution of 222 plant species (Table 1) from the total 249 plant species recorded by Al Khulaidi (2), Al Khulaidi & Kessler (4), Wood (48), Al Khulaidi & Dubaie (3) and Al Hubaishi & Muller-Hohenstein, (1) among the African paleotropical floristic elements, by utilizing the following floristic literatures: Richard (35, 34); Masters (31); Baker (9); Hooker (24); Hiern (23); Broun et al (17); Schwartz (37); Andrews (6, 7& 8); Zohary (49); Wickens (47); Takhtajan (40); Johns (28); White and Leonard (46); Jefferey & Thulin (27); Thulin (43, 42); Battandier (10); Boulos (12, 13, 14, 15, 16); Cope (19&20); Tamado & Milberg (41); Hepper (22); Snogerup & Boulos (38); Ali & Boulos (5); Burrows & Willis (18); Scholte, et.al (36); Snogerup & Snogerup (39); Frits et al. (21); Hutchinson et al. (25) and Ibrahim et al (26).

Moreover, the distribution of 222 plant species, among the African paleotropical floristic elements, was subjected to numerical analysis (UPGMA method) to investigate the links between the 10 African paleotropical floristic elements.

Results

Table 1. Distribution of species among the 10 African paleotropical floristic elements

| Plant species | Fer | Adiantum capillus-veneris L. | Equisetum ramosissimum Desf. | Gym | Juniperus procera Hochst. ex Endl. | Dicotyledon | Acacia etbaica Schweinf | Acacia gerrardii Benth. | Acacia origina Asfaw | Acanthus arbores Forssk. | Achyranthes aspera L. | Aerva javanica (Burm.f.) Juss. ex Schult. |
|---------------|-----|-----------------------------|-----------------------------|-----|----------------------------------|-------------|------------------------|------------------------|----------------------|----------------------|------------------------|-----------------------------|
| Phytogeographical elements | SS | Sa | S | A | M | f | Z | I | C | S | G | GC | GC |
|-----------------------------|---|----|---|---|---|---|---|---|---|---|---|---|----|
| Adiantum capillus-veneris L. | + | + | + | + | + | + | + | + | + | + | + | + |
| Equisetum ramosissimum Desf. | + | + | + | + | + | + | + | + | + | + | + | + |
| Juniperus procera Hochst. ex Endl. | - | + | + | + | + | + | - | - | - | - | - | - |
| Acacia etbaica Schweinf | + | + | + | + | + | + | + | + | + | + | + | + |
| Acacia gerrardii Benth. | - | + | + | + | + | + | + | + | + | + | + | + |
| Acacia origina Asfaw | - | - | - | + | + | + | - | - | - | - | - | - |
| Acanthus arbores Forssk. | - | + | + | + | + | + | + | + | + | + | + | + |
| Achyranthes aspera L. | + | + | + | + | + | + | + | + | + | + | + | + |
| Aerva javanica (Burm.f.) Juss. ex Schult. | + | + | + | + | + | + | + | + | + | + | + | + |
| Species                                                                 | Presence |
|------------------------------------------------------------------------|----------|
| Alkanna orientalis (L.) Boiss.                                         | -        |
| Althaea ludwigii L.                                                    | +        |
| Amaranthus hybridus L.                                                 | +        |
| Anagallis arvensis L.                                                  | +        |
| Anarrhinum forsskaloii (J.F.Gmel.) Cufod.                              | -        |
| Anastatica hierochuntica L.                                            | +        |
| Anchusa arvensis (L.) M. Bieb.                                         | -        |
| Andrachna aspera Spreng.                                               | +        |
| Aptium nodiflorum (L.) Lag.                                            | +        |
| Argemone mexicana L.                                                   | +        |
| Argyrolobium arabicum (Decne.) Jaub. & Schap.                          | +        |
| Artemisia abyssinica Sch. Bip. ex A. Rich.                             | -        |
| Astragalus sieberi DC.                                                 | +        |
| Astragalus tribuloides Delile                                          | +        |
| Astragalus vogelli (Webb) Bornm.                                       | +        |
| Atriplex leucocloa Boiss.                                              | +        |
| Berula erecta (Huds.) Coville                                         | +        |
| Blepharis ciliaris (L.) B. L. Burtt                                    | -        |
| Boerhavia boissieri Heimerl                                            | +        |
| Boerhavia diffusa L.                                                  | +        |
| Boerhavia heleneae Roem. & Schult                                     | +        |
| Boerhavia pedunculosa A.Rich.                                          | -        |
| Boerhavia sinuata (Meikle) Greuter & Burdet                            | +        |
| Calendula arvensis (Vaill.) L.                                         | +        |
| Calotropis procera (Aiton) Dryand.                                     | +        |
| Capparis cartilaginea Decne.                                           | +        |
| Caylusea hexagyna (Forssk.)                                            | +        |
| M.L.Green                                                              | +        |
| Centella asiatica (L.) Urb.                                            | -        |
| Chenopodium murale L.                                                  | +        |
| Chenopodium procerum Hochst. ex Moq.                                   | -        |
| Chenopodium schraderianum Schult .                                     | -        |
| Chrozophora oblongifolia (Delile A.Juss. ex Spreng)                    | +        |
| Cirsium vulgare (Savi) Ten.                                            | -        |
| Cissus rotundifolia Vahl                                               | -        |
| Citrullus colocynthis (L.) Schrad.                                     | +        |
| Cleome amblyocarpa Barratte & Murb.                                    | +        |
| Cleome brachycarpa (Forssk.) Vahl ex DC.                               | +        |
| Cometes abyssinica R.Br. ex Wall.                                      | +        |
| Convolvulus arvensis L.                                                | +        |
| Conyza incana (Vahl) Wild.                                             | -        |
| Species                                                                 | Presence Score |
|------------------------------------------------------------------------|----------------|
| Conyza pyrrhopappa Sch.Bip. ex A.Rich.                                | - - + + + + - + + + |
| Crepis rueppellii Sch.Bip.                                            | - + - - + - - - - |
| Crotalaria emarginata Vatke                                            | - - + + - - + - - |
| Cucumis prophetarum L.                                                | + + + + + + - + + |
| Datura stramonium L.                                                   | + + + + + + + + + |
| Desmodorichis penicillata (Defters) Plowes                            | - + - - + - - - - |
| Diplotaxis erucoides (L.) DC.                                         | + + - + + + - - - |
| Echinops spinossimus Turra                                            | + + + + - + + + - |
| Echium rauwolfii Delile                                               | + + + - - - - - - |
| Erigeron bonariensis L.                                                | + + + - + - - - - |
| Erigeron trilobus (Decne.) Boiss.                                     | + + + + + + + + + |
| Erodium cicutarium (L.) L'Hér.                                        | + - - - + - - - - |
| Erodium malacoides (L.) L'Hér.                                         | + + - + - - - - - |
| Erucastrum arabicum Fisch. & C.A.Mey.                                  | + + + + + + + + + |
| Euphorbia cactus Ehrenb. ex Boiss.                                    | - - + + - - - - - |
| Euphorbia granulata Forssk.                                            | + + + + + + + - + |
| Euphorbia helioscopia L.                                               | + - - - - - - - - |
| Euphorbia inaequilatera Sond.                                         | + + + + + + + + + |
| Euphorbia peplus L.                                                   | + + - - + + - - - |
| Euphorbia schimperi C. Presl                                         | - + - - - - - - - |
| Euphorbia schimperiana Scheele                                        | + + + + + + + + + |
| Euryops arabicuus Steud. ex Jaub. & Spach                             | - - + + + - - - - |
| Fagonia bruguieri DC.                                                 | + + + + + + - - + |
| Fagonia indica Burm.f.                                                | + + + + + + + - - |
| Fagonia paulayana J.Wagner & Vierh.                                   | + + + + + + + - - |
| Falkia oblonga Bernh.                                                 | - - - - + - - - - |
| Farsetia longisilica Decene.                                          | + + + + + - - - - |
| Felicia abyssinica Sch. Bip. ex A. Rich.                              | - - + + + - - - - |
| Felicia dentata (A. Rich.) Dandy                                      | + + + + + - - - - |
| Ficus palmata Forssk. ssp. palmate                                    | + + + + + - - - - |
| Flaveria trinervia (Spreng.) C. Mohr                                   | - - - - + - - - - |
| Forsskaolea tenacissima L.                                            | + + + + + + + - - |
| Galium tricornutum Dandy                                              | + - - - - - - - - |
| Geranium biuncinatum Kokwaro                                         | + + + + + - - - - |
| Gnidia somalensis (Franch.) Gilg                                      | - - + - - - - - - |
| Gomphocarpus fruticosus (L.) W. T. Aiton                              | + + + + + + + + + |
| Helichrysum schimperi (Sch. Bip. ex A. Rich.) Moeser                  | - + + + + - + + + |
| Helichrysum somalense Baker f.                                        | - - - + - - - - - |
| Heliotropium crispum Desf.                                            | + + + - - + + + - |
| Heliotropium europaeum L.                                             | + - + - - - - - - |
| Heliotropium longiflorum (A.DC.) Jaub. & Spach                        | - + + + + + - - - |

**The African Paleotropical Floristic …….Hassan Ibrahim, Hana Saleh, Abdul Nasser Al-Gifri**
| The African Paleotropical floristic ..........Hassan Ibrahim, Hana Saleh, Abdul Nasser Al-Gifri |
|---------------------------------------------|
| **Heliotropium steudneri** Vatke - + - + + - + - + |
| **Hibiscus trionum** L. + + + + + + + + + + |
| **Hypoestes forsskaolii** (Vahl) R. Br. - + + + + + + + + + + |
| **Indigofera arabica** Jaub. & Spach + + + + + + + + + + + |
| **Indigofera spinosa** Forssk. + + + + + + + - - - |
| **Kickxia elatine** (L.) Dumort. + - - - - - - - - - |
| **Kleinia odora** (Forssk.) DC. - - - + - - - - - - - |
| **Kleinia semperviva** DC. - - - + - - - - - - - |
| **Laggera decurrens** (Vahl) Hepper & J. R. I. Wood + + + - - - - - - + - |
| **Laphangium luteoalbum** (L.) Tzvelev - - + - - + + + + |
| **Launaea capitata** (Spreng.) Dandy + + + + - - - - - - - |
| **Launaea nudicaulis** (L.) Hook. f. + + + + - - - - - + - |
| **Lavandula coronopifolia** Poir. + + + + - - - - - - - |
| **Lepidium draba** L. + + + - + + + + + + + |
| **Leucas inflata** Benth. + + + + - - - - - - - |
| **Lotononis platycarpus** (Viv.) Pic. Ser. + + + + + + + + - - - |
| **Lotus corniculatus** L. + + - - + - - - - - - - |
| **Lotus quinatus** (Forssk.) J. B. + + - - + - - - - - - - |
| **Gillet** - - + + - - - - - - - |
| **Lycium shawii** Roem. & Schult. + + + + + - - + - - - |
| **Lythrum hyssopifolia** L. + + + + + + + + + + + |
| **Malva parviflora** L. + + + + + + + + + + + |
| **Malva verticillata** L. - + + + + - - - - - - - |
| **Medicago lupulina** L. + + + + + + + - - - - - |
| **Mentha longifolia** (L.) L. + - - + + + + + + + + |
| **Micromeria imbricata** (Forssk.) C. Chr. + + + + + + + + + + + |
| **Myriophyllum spicatum** L. + + - - + - - - - - - - |
| **Notoceras bicorne** (Aiton) Amo + + - - - - - - - - - - |
| **Ostostegia fruticosa** (Forssk.) Schweinf. + + - - - - - - - - - - |
| **Oxalis corniculata** L. + + + + + + + + + + + |
| **Peganum harmala** L. + - - - - - - - - - - - |
| **Persicaria amphibia** (L.) Delarbre - - - - - + - - - - - |
| **Phyla nodiflora** (L.) Greene + + + + + + + + + + + |
| **Plantago lanceolata** L. + + + + + + + + + + + |
| **Plantago major** L. + + + + + + - - - - - - |
| **Plantago ovata** Forssk. + - - - - - - - - - - - |
| **Polycarpaea repens** (Forssk.) Asch. & Schweinf. + + + + + + + + + + + |
| **Polycarpaea robbairesa** (Kuntze) Greuter & Burdet + + - - - - - - - - - - |
| **Polygala erioptera** DC. + + + + + + + + + + + |
| **Polygnumum aviculare** L. + + + + + + + + + + + |
| **Portulaca quadridifida** L. + + + + + + + + + + + |
| **Potentilla reptans** L. + - - + + - - - - - - - |
| **Psiadia punctulata** (DC.) Vatke + - - + + + - - - - - - |

Univ. Aden J. Nat. and Appl. Sc. Vol. 23 No.1 – April 2019 155
### The African Palaeotropical Floristic

| Plant Name                      | Presence Pattern |
|---------------------------------|------------------|
| *Pulicaria inulooides* (Poir.) DC. | + + + + + - - - - |
| *Pulicaria jaubertii* E. Gamal-Eldin | + - - + + - - - - |
| *Pulicaria undulata* (L.) C. A. Mey. | + + + + + + + + |
| *Ranunculus multifidus* Forssk.     | - + + + + + + + |
| *Reichardia tingitana* (L.) Roth     | + + + + + + + - |
| *Rhynchosia minima* (L.) DC.          | + + + + + + + + |
| *Ricinus communis* L.               | + + + + + + + + |
| *Rosa abyssinica* R.Br. ex Lindl.     | - + + + + - - - - |
| *Rumex dentatus* L.                 | + - - - - - - - - |
| *Rumex nervosus* Vahl               | - + + + + + + - - |
| *Salix steudelii* Hochst. ex A. Rich. | - + + + + + + + |
| *Salix mucronata* Thunb.            | + - - + + + - - - |
| *Salix triandra* Boiss.             | - - - + - - - - - |
| *Salvia aegyptiaca* L.              | + + + + - - - - - |
| *Salvia schimperi* Bentham          | - - - - + - - - - |
| *Sageretia thea* (Osbeck) M.C. Johnst. | + - - - + - - - - |
| *Seneio schimperi* Sch. Bip. ex A. Rich. | - + + + + + + + + |
| *Senna italica* Mill.              | + + + + + + + + |
| *Sisymbrium irio* L.                | + + - - + + + + |
| *Solanum glabratum* Dunal           | - - - - + - - - - |
| *Solanum incanum* L.               | + + + + + + + + |
| *Solanum nigrum* L.                 | + + + + + + + + |
| *Solanum villosum* Mill.            | + + + + + + + + |
| *Sonchus oleraceus* (L.) L.         | + + + + + + + + |
| *Spergularia marina* (L.) Besser    | + - - - - - - - - |
| *Suaeda aegyptiaca* (Hasselq.) Zohary | + + + + + - - - - |
| *Tamarix senegalensis* DC.          | + + - + - - - - + |
| *Telephium sphaeroperum* Boiss.     | + - - + + + - - - |
| *Tragia pungens* (Forssk.) Müll. Arg. | - + + + - - - - - |
| *Triahthema crystallina* Vahl       | + + - + + - - - - |
| *Tribulus terrestris* L.            | + + + + + + + + |
| *Trichodesma africanaum* (L.) Sm.   | + + + + + + + + |
| *Trifolium fragiferum* L.           | + + - + - - - - - |
| *Tripteris vaillantii* Decne.       | + + + + + + + - - |
| *Verbena officinalis* L.            | + + + + + + + + |
| *Veronica polita* Fr.               | + - - - - - - - - |
| *Volataria abyssinica* (Sch.Bip. ex A.Rich.) C.Jeffrey ex Cufod. | - - - + + - - - - |
| *Withania somnifera* (L.) Dunal     | + + + + + + + + |
| *Xanthium spinosum* L.              | + - - + - - - - - |
| *Ziziphus spinosa-christi* (L.) Desf. | + + + + + + + + |
| *Aeluropus lagopoides* (L.) Thwaites | + + + + - - - - + |
| *Andropogon greenwayi* Napper       | - - - + + + + - - |
| *Aristida adscensionis* L.          | + + + + + + + + + |
| *Aristida congesta* Roem. & Schult. | - - - + + - - - - |
| *Avena abyssinica* Hochst.          | - - - + + + + - - |
| *Brachiaria eruciformis* (Sm.) Griseb. | + + + + + + + + |

**Dicotyledon**

**Monocotyledon**
| Species (Linnaeus) Authority | Presence | Presence | Presence | Presence | Presence | Presence | Presence | Presence | Presence | Presence |
|-----------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Carex distans L.            | +        | +        | +        | +        | +        | +        | -        | -        | -        | -        |
| Chenopodium album L.         | +        | +        | +        | -        | -        | -        | -        | -        | -        | -        |
| Chrysanthemum indicum (Desf.) | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Chrysanthemum leucanthemum (L.) | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Dianthus caryophyllus (L.)    | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Euphorbia myrsinites (L.)     | +        | +        | +        | -        | -        | -        | -        | -        | -        | -        |
| Eryngium planum (L.)         | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Helianthus annuus (L.)       | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Helianthus tuberosus (L.)    | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Levisticum officinale (L.)   | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Nicotiana tabacum (L.)       | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Peucedanum officinale (L.)   | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Pyrus communis (L.)          | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa canina (L.)             | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa banksiae (L.)           | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa chinensis (L.)          | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa gallica (L.)            | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa multiflora (L.)         | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa rubiginosa (L.)         | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa rugosa (L.)             | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa spinosissima (L.)       | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa xanthina (L.)           | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |

**Monocotyledon**

| Species (Linnaeus) Authority | Presence | Presence | Presence | Presence | Presence | Presence | Presence | Presence | Presence | Presence |
|-----------------------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Carex distans L.            | +        | +        | +        | +        | +        | +        | -        | -        | -        | -        |
| Chenopodium album L.         | +        | +        | +        | -        | -        | -        | -        | -        | -        | -        |
| Chrysanthemum indicum (Desf.) | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Dianthus caryophyllus (L.)   | +        | +        | +        | -        | -        | -        | -        | -        | -        | -        |
| Euphorbia myrsinites (L.)    | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Eryngium planum (L.)         | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Helianthus annuus (L.)       | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Helianthus tuberosus (L.)    | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Levisticum officinale (L.)   | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Nicotiana tabacum (L.)       | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Peucedanum officinale (L.)   | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Pyrus communis (L.)          | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa canina (L.)             | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa banksiae (L.)           | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa chinensis (L.)          | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa gallica (L.)            | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa multiflora (L.)         | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa rubiginosa (L.)         | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa rugosa (L.)             | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa spinosissima (L.)       | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |
| Rosa xanthina (L.)           | +        | +        | +        | +        | +        | +        | +        | +        | +        | +        |

**The African Paleotropical floristic ……..Hassan Ibrahim, Hana Saleh, Abdul Nasser Al-Gifri**

Univ. Aden J. Nat. and Appl. Sc. Vol. 23 No.1 – April 2019
The African Pal
eotropical floristic ……..Hassan Ibrahim, Hana Saleh, Abdul Nasser Al-Gifri

| Plant Name                  | SS1 | Sa | S  | Z  | Af | ZI  | SM | GC  |
|----------------------------|-----|----|----|----|----|-----|----|-----|
| Tetrapogon villosus Desf.  | +   | +  | +  | -  | -  | +   | -  | -   |
| Themeda triandra Forssk.   | +   | +  | +  | +  | +  | +   | +  | +   |
| Tragus racemosus (L.) All. | +   | +  | +  | +  | +  | +   | +  | +   |

SS1: Saharan regional subzone, Sa: Sahel regional transition zone, S: Sudanese regional central of endemism, SM: Somalia- Masai regional centre of endemism, Af: Afrotropical archipelago-like regional centre of endemism, Z: Zambezian regional central of endemism, ZI: Zanzibar-Inhambane regional mosaic, GC: Guineo-Congolian regional centre of endemism, GCS: Guinea-Congolian/ Soudania regional transition zone & GCZ: Guinea-Congolian/ Zambezia regional transition zone.

103 species (41.4 %), respectively (Tables 1-2 & Fig. 1), followed by Sahara Regional Subzone (SS1) with 158 (63.5 %) species and Guinean Region with 106 (42.6%) species. Guineo-Congolian Centre of Endemism (GC) is represented by 82 species (32.9 %), whereas Guinea-Congolian / Sudanese Regional Transition Zone (GCS) & Guinea-Congolian / Zambezia Regional Transition Zone (GCZ) are represented by 99 (39.8 %) & 75 (31.3 %) plant species, respectively.

According to the chorological analysis, about 59 (23.7%) of all recorded species in the flora of Highland plains in Yemen are monoregional, of which 44 species (17.7%) are native to the Sudano-Zambezian Region, followed by the Saharo-Arabian Region with 15 species (6%). Although biregional categories are represented by 77 species (30.9%) of all recorded species in the flora of Highland plains. Of these, the categories of the Saharo-Arabian Region and Sudan-Zambezi Region are represented by 57 (22.9%) species, while the categories of the Sudano-Zambezi Region and Guinean Region are represented by 20(8%) species. On the other hand, the triregional categories are represented by 86 (34.5%) species (Table 2).

![Fig. 1. Distribution of species among the 10 African paleotropical elements.](image-url)

Abbreviations see Table 1.
### Table 2. Mono, bi & tri-regional species

| Phytogeographical regions / phytogeographical categories | No. of Species | Percentage (%) of the total No. of Species recorded from Highland plains |
|-----------------------------------------------------------|----------------|--------------------------------------------------------------------------------|
| **Monoregional:**                                         |                |                                                                                |
| Saharo-Arabian region                                     | 15             | 6%                                                                              |
| SS1                                                       |                |                                                                                |
| **Total**                                                 | 15             | 6%                                                                              |
| **Sudano-Zambezian region:**                             |                |                                                                                |
| Sa                                                        | 1              |                                                                                |
| SM.                                                       | 4              |                                                                                |
| Af.                                                       | 10             |                                                                                |
| Z                                                         | 1              |                                                                                |
| Sa+Af                                                     | 2              |                                                                                |
| SM+Af                                                     | 8              |                                                                                |
| SM+Af+Z.                                                  | 2              |                                                                                |
| Sa+ SM+Af+Z.                                             | 5              |                                                                                |
| Sa+ SM+Af+ZI.                                            | 2              |                                                                                |
| Sa+SM+Af+Z+ZI.                                           | 3              |                                                                                |
| Sa+SM+Af+Z+ZI.                                           | 1              |                                                                                |
| Sa+SM+Af+Z+ZI.                                           | 1              |                                                                                |
| Sa+SM+Af+Z+SM+Af+ZI.                                     | 5              |                                                                                |
| Sa+SM+Af+Z+SM+Af+ZI.                                     | 1              |                                                                                |
| Sa+SM+Af+Z+SM+Af+Z+ZI.                                   | 4              |                                                                                |
| **Total**                                                 | 44             | 17.7%                                                                          |
| **Total number of monoregional species**                  | 59             | 23.7%                                                                          |
| **Biregional:**                                          |                |                                                                                |
| Saharo-Arabian region + Sudano-Zambezian region           |                |                                                                                |
| SS1+ Sa.                                                 | 3              |                                                                                |
| SS1+ S.                                                  | 1              |                                                                                |
| SS1+ SM.                                                 | 1              |                                                                                |
| SS1+Af.                                                  | 3              |                                                                                |
| SS1+ Sa+S.                                               | 1              |                                                                                |
| SS1+ Sa+ Af.                                             | 3              |                                                                                |
| SS1+ SM+ Af.                                             | 5              |                                                                                |
| SS1+ Sa+ S+ SM.                                          | 2              |                                                                                |
| SS1+ Sa+ S+ Af.                                          | 1              |                                                                                |
| SS1+ Sa+ SM+ Af.                                         | 6              |                                                                                |
| SS1+ SM+ Af+ Z.                                          | 2              |                                                                                |
| SS1+ SM+ Af+ ZI.                                         | 1              |                                                                                |
| SS1+ Sa+ S+ SM+ Af.                                      | 15             |                                                                                |
| SS1+ S+ SM+ Af+ Z.                                       | 1              |                                                                                |
| SS1+ Sa+ SM+ Af+ Z+ ZI.                                  | 1              |                                                                                |
| SS1+ Sa+ S+ SM+ Af+ Z+ ZI.                               | 11             |                                                                                |
| **Total**                                                 | 57             | 22.9%                                                                          |
| **Sudano-Zambezian region + Guinean region:**             |                |                                                                                |
| S+ Af+ GC+ GCS.                                          | 1              |                                                                                |
| SM+ Z+ ZI+ GCS.                                          | 1              |                                                                                |
| Sa+ S+ SM+ Af+ Z+ ZI+ GC.                                | 1              |                                                                                |
| Sa+ SM+ Af+ Z+ ZI+ GC+ GCZ.                              | 1              |                                                                                |
| S+ SM+ Af+ Z+ GC+ GCS+ GCZ.                              | 1              |                                                                                |
The African Pal
eotropical floristic ………..Hassan Ibrahim, Hana Saleh, Abdul Nasser Al-Gifri

| Species Composition         | Species Count |
|-----------------------------|---------------|
| Sa+ S+ SM+ Af+ Z+ ZI+ GC+ GCS. | 1             |
| Sa+ S+ SM+ Af+ Z+ GC+ GCS+ GCZ. | 1             |
| S+ SM+ Af+ Z+ ZI+ GC+ GCS+ GCZ. | 2             |
| Sa+ S+ SM+ Af+ Z+ ZI+ GC+ GCS+ GCZ. | 11            |
| **Total**                   | **20**        |
| **Total number of biregional species** | **77**        |

Tri-regional:
Saharo-Arabian region + Sudano-Zambezan Region + Guinean Region

| Species Composition         | Species Count |
|-----------------------------|---------------|
| SS1+ Sa+ S+ GCS.            | 1             |
| SS1+ S+ SM+ GCS.            | 1             |
| SS1+ Sa+ S+ SM+ GCS.        | 2             |
| SS1+ Sa+ SM+ Af+ GCS.       | 1             |
| SS1+ Sa+ S+ GC+ GCS.        | 1             |
| SS1+ Sa+ Z+ GC+ GCZ.        | 1             |
| SS1+ S+ SM+ Af+ GCS.        | 1             |
| SS1+ Sa+ S+ SM+ Af+ GCS.    | 5             |
| SS1+ Sa+ S+ SM+ Af+ GC.     | 2             |
| SS1+ Sa+ S+ SM+ Z+ GCS.     | 1             |
| SS1+ Sa+ S+ Af+ GC+ GCS.    | 1             |
| SS1+ SM+ Af+ Z+ ZI+ GC+ GCS. | 1             |
| SS1+ Sa+ S+ SM+ Af+ Z+ ZI+ GCS. | 1             |
| SS1+ Sa+ S+ SM+ Af+ Z+ ZI+ GC. | 2             |
| SS1+ Sa+ S+ SM+ Af+ Z+ ZI+ GC+ GCS. | 5             |
| SS1+ Sa+ S+ SM+ Af+ Z+ GC+ GCS+ GCZ. | 1             |
| SS1+ Sa+ S+ Af+ Z+ GC+ GCS+ GCZ. | 1             |
| SS1+ Sa+ S+ SM+ Af+ Z+ ZI+ GC+ GCS. | 1             |
| SS1+ Sa+ S+ SM+ Af+ Z+ ZI+ GC+ GCS+ GCZ. | 3             |
| SS1+ Sa+ S+ SM+ Af+ Z+ ZI+ GC+ GCS+ GCZ. | 3             |
| SS1+ Sa+ S+ SM+ Af+ Z+ ZI+ GC+ GCS+ GCZ. | 50            |
| **Total**                   | **86**        |
| **Total number of tri-regional species** | **86**        |

The total number of species shows distribution
relationships with the African
phytogeographical regions

222

*For abbreviations see Table 1.

The dendrogram resulting from the UPGMA method divides the 10 African paleotropical floristic elements on the basis of their species composition into two main groups (Group I & Group II) at a relative similarity level of 66.72 %.

Group I includes the Saharo-Sindian Region element (Saharan Regional Subzone) and 4 elements of the Sudano-Zambezan Region (Sudanian Regional Transition Zone, Sudanese Regional.

Centre of Endemism, Somalia- Masai Regional Centre of Endemism & Afro-Montane Archipelago-Like Regional Centre of Endemism) which are located north and north east of the Equator; while Group II includes the two remaining elements of the Sudano-Zambezan Region (Zambezi Regional Centre of Endemism & Zanzibar-Inhambane Regional Mosaic) which are located south of the Equator and all the elements of the Guinean Region (Guineo-Congolian Centre of Endemism, Guinea-Congolian / Sudania Regional Transition Zone & Guinea-Congolian / Zambezia Regional Transition Zone). Furthermore, Group I & Group II are divided in two
subgroups; A&B at relative similarity level of 76.59% and C&D at relative similarity level of 76.61% respectively.

Subgroup A includes the Saharo-Sindian Region element (Saharan Regional Subzone); while Subgroup B includes two clusters (1&2) at relative similarity level of 83.63%, cluster1 includes Somalia- Masai Regional Centre of Endemism & Afro-Montane Archipelago-Like Regional Centre of Endemism at relative similarity level of 90.25%, while cluster 2 includes Sahel Regional Transition Zone, Sudanese Regional Centre of Endemism at relative similarity level of 90%. Moreover, subgroup C includes Zambezi Regional Centre of Endemism & Zanzibar-Inhambane Regional Mosaic at relative similarity level of 90.41%. On the other hand, subgroup D includes two clusters (3&4) at relative similarity level of 83.39%; cluster 3 includes the Guinea-Congolian / Sudania Regional Transition Zone; while cluster 4 includes Guinea-Congolian Centre of Endemism & Guinea-Congolian / Zambezia Regional Transition Zone at relative similarity level of 90.45% (Fig. 2).

**Discussion**

According to the previous phytogeographical analysis, 207 (83.1%) species from the flora of Yemen highland plains of show more distribution relationships with the Sudano-Zambezian Region then other two African paleotropical floristic regions although about 184 (73.9 %) plant species show more distribution relationships with Afro-Montane Archipelago-Like Regional Centre of Endemism more than the other nine African paleotropical floristic elements. Then, the flora of highland plains of Yemen is more like Afro-Montane Archipelago-Like Regional Centre of Endemism than Somalia- Masai Regional Centre of Endemism and Saharo-Sindian Region which boarded the mountains of Yemen (including of highland plains of Yemen) from the south and the east respectively. This corresponds to the findings of White and Leonard (46), which placed the southwestern mountains of the Arabian Peninsula (including mountains & highland plains of Yemen) within the Afro-Montane Archipelago- Like Regional Centre of Endemism.
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الملخص

حوالي 222 نوعاً نباتياً (نوعان من السرخس، واحد من عاريات البذور، 219 كاسيات البذور: 169 من ذوات الفلقتين و 50 من ذوات الفلقة) من إجمالي 249 نوعاً مسجلت من سهول المرتفعات في اليمن، أظهروا علاقة التوزيع مع ثلاث مناطق نباتية مدارية أفريقية من المملكة النباتية الاستوائية القديمة و 10 أقاليم نباتية مدارية أفريقية من المملكة النباتية الاستوائية القديمة. وقد خضعت علاقة التوزيع بين ال 10 الأقاليم النباتية المدارية الأفريقية للتحليل العددي: و كان الإقليم السوداني – الزنبيزي يضم العدد الأكبر من الأنواع النباتية 207 (83.1٪) نوعاً نباتياً التي أظهر علاقة توزيعه مع سهول المرتفعات في اليمن، ومن ناحية أخرى وجد أن الإقليم الجبال الأفريقية يضم العدد الأكبر من الأنواع النباتية (مقارنة بباقي الأقاليم) 184 (73.9٪) نوعاً نباتي الذي أظهر علاقة توزيعه مع سهول المرتفعات في اليمن.

الكلمات المفتاحية: فريقا، أقاليم نباتية، تحليل عددي، المملكة النباتية الاستوائية القديمة، سهول المرتفعات.