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Segregation of *Polygonum* (Tourn) L. from *Persicaria* Mill. using morphological characteristics

Usama K. Abdel-Hameed*, Safia A. A. Mohammed, Maysa M. Hatata

Department of Biology, College of Science, Taibah University, Madinah, Saudi Arabia.
*Corresponding author E-mail: *uabdelhameed@taibahu.edu.sa*

Abstract

It has long been required to divide the diverse genus *Polygonum s.l.* into smaller groups. The main objectives of the current investigation are to assess the ability of morphological characters to contribute to the segregation of *Polygonum* (Tourn) L. from *Persicaria* Mill., in addition to conduct principal component analysis to know the most valuable morphological characters that may be used for this separation. The morphological characters of four species of *Persicaria* and six species of *Polygonum* were taken out and exposed to phenetic and PCA that was carried out to identify the key traits that distinguish the studied taxa. It is determined that the selected morphological features were crucial in delimitation of species where the first two primary components accounted for about half (45.35%) of the overall morphological variances, demonstrating the significant variety of the morphological characteristics, which is helpful for differentiation, and these traits were used to illustrate the phenetic links among the studied taxa of *Polygonum* and *Persicaria*.

Keywords: Morphological correlation, PAST, PCA, Phenogram, Polygonaceae.

Introduction

The primary aim of the present study is to assess the ability of morphological characters to contribute to the segregation of *Polygonum* (Tourn) L. from *Persicaria* Mill., in addition to conduct principal component analysis to know the most valuable morphological characters that may be used for this separation. The division of the diverse genus *Polygonum s.l.* into smaller units has been necessary according to some proposals Meissner and De Candolle (1864); Haraldson (1978); Decraene and Akeroyd (1988); Hong et al. (1998) subdivided genus *Polygonum* L. into 7 sections *viz*. Aconogonon, Amblygonon, Avicularia, Bistorta, Fagopyrum, Persicaria, and Tiniaria. Meissner and De Candolle (1864) expanded these sections to nine (Amblygonon, Aconogonon, Avicularia, Bistorla, Cephalophilon, Echinocaulon, Persicaria, Tiniaria, Tephis), and segregated *Fagopyrum* and *Pobgonella* as separate genera. Hooker and Bentham (1880) included a few groups (Pseudomollia, Pseudopolygonella and Pleuropterus). Watson (1873) segregated section Duravia, with *P. californicum* as a single species. Gross (1971) identified different genera within *Polygonum*; (*Bistorta*, *Fagopyrum*, *Pleuropterus, Pteroxygonum, Pleuropteropyrum, Polygonurn s.s.* and *Persicaria*) based on morphological characters. Hedberg (1946) divided *Polygonum* into 7 genera, primarily based on morphology of pollen grains *(Bistorta*, *Fagopyrum*, *Koenigia, Persicaria, Polygonurn s.s., Pleuropteropyrum,* and *Tiniaria*). Haraldson (1978) suggested a comparable approach and identified 8 genera *(Aconogonon*, *Bistorta, Fagopyrum*, *Fallopia, Koenigia, Persicaria, Polygonurn*, and *Reynoutria)* in 2 distinct tribes, primarily due to anatomical features, in addition she divided *Polygonum s.l.* into Polygoneae and Persicarieae.

Grouping *Persicaria* and *Polygonum sensu stricto* is strange, Only their more distant affinities can connect them despite their apparent similarity within the subfamily Polygonoideae. Based on some morphological characters, *Persicaria* is best preserved as a different genus and kept apart from *Polygonum s.s.*Stanford (1925); Hedberg (1946); Gross (1971); Haraldson (1978).

Materials and Methods

The current investigation was carried out on four species of *Persicaria* and six species of *Polygonum Viz*. *Persicaria decipiens* (R. Br.) K. L. Wilson -- Telopea 3(2): 178 (1988) = *Persicaria salicifoliIa* (Brouss. ex Willd.) Assenov = *Polygonum decipiens* R. Br. = *Polygonum salicifolium* Brouss. Ex Willd. = *Polygonum serrulatum* Lag., *Persicaria lanigera* (R. Br.) Soják -- Preslia 46(2): 153. 1974 = *Polygonum lanigerum* R. Br., *Persicaria lapathifolia* (L.) Gray -- Nat. Arr. Brit. Pl. ii. 270. = *Polygonum lapathifolium* L. = *Polygonum tomentosum* Schrank, *Persicaria senegalensis* (Meisn.) Soják -- Preslia 46(2): 155. 1974 = *Polygonum senegalense* Meisn., *Polygonum aviculare* L., Sp. Pl. 1: 362 (-363) (1753)., *Polygonum bellardii* All., Fl. Pedem. 2: 205 (1785)., *Polygonum equisetiforme* Mayer ex Ten. -- Syll. Pl. Fl. Neapol. 195. 1831, *Polygonum maritimum* L., Sp. Pl. 1: 361 (1753)., *Polygonum patulum* M. Bieb. -- Fl. Taur.-Caucas. 1: 304. 1808., *Polygonum plebeium* R.Br., Prodr. Fl. Nov. Holland. 420. (1810). Table (1) summarized the clearly visible (51) character states of (22) morphological features. Herbarium specimens from Ain Shams University's Faculty of Science (CAIA), Cairo University's Faculty of Science (CAI), the Flora and Phytotaxonomy Research Department (CAIM), and the Orman Botanical Garden in Giza were used to study these features. Additionally, published descriptions were consulted. El Gazzar et al. (2023). The nomenclature and identity were verified using Täckholm (1974); Boulos (2005) and International Plant Name Index IPNI (2012).

Morphological characters states by taxon matrix was underwent to phenetic analysis by using PAleontological STatistics Version 3.23 Hammer et al. (2001). Principal component analysis (PCA) ordination and similarity matrix were performed by the same program, depending on the examined morphological traits of the subjected taxa.

Table 1. The morphological traits, states, and codes of the species under study that were extracted.

No.	Character	Character state and its (code)
1.	Life cycle	Perennial (0) Annual (1)
2.	Habit	Herb (0) Shrub (1)
3.	Strength	Erect (0) Prostrate (1)
4.	Bark color	Glabrous (0) Wooly (1)
5.	Stem branching	From base (0) Lateral (1)
6.	Leaves duration	Persistent (0) Deciduous (1)
7.	Texture	Glabrous (0) Wooly (1)
8.	Lamina shape	Sagittate (0) Orbicular (1)
9.	Lamina margin	Entire (0) Undulate (1)
10.	Lamina elevation	Flat (0) Revolute (1)
11.	Lamina apex	Acute (0) Acuminate (1)
12.	Ochrea union	Connate (0) Bifid (1)
13.	Ochrea colour	Pink (0) Transparent (1)
14.	Inflorescence type	Raceme (0) Spike (1) cluster (2)
15.	Flower	Pedicelled (0) Sessile (1)
16.	Perianth segments	Four (0) Five (1) Six (2)
17.	Perianth colour	White (0) Pink (1) Pale-green (2)
18.	Perianth tube	Absent (0) Present (1)
19.	No. of stamens	Five (0) Six (1) More than six (2)
20.	No. of Styles	One (0) Two (1) Three (2)
21.	Nutlet colour	Black (0) Brown (1)
22.	Nutlet shape	Oblong (0) Lenticular (1) Trigonous (2) Biconvex (3)

Results

The phenetics depending on the coded morphological data matrix of the studied taxa produced a dendrogram (figure 1) that is branched into two distinct groups; one consists of the studied taxa of genus *Persicaria* at less than 0.52 taxonomic distance, while the taxa of *Polygonum* are grouped in the second group at about 0.67 similarity index. within *Persicaria* group, *P lanigera* is the first taxon which separated followed by *P senegalensis*, while *P lapathifolia* and *P decipiens* formed a sister-relationship. On the other hand, within *Polygonum* group, *P. equisetiforme* separated at basal level, the remaining taxa distributed into two sub-groups; the first one consisted from three taxa; *P. bellardii*, *P. plebeium* and *P. maritimum*, the second sub-group contained *P. patulum* and *P. aviculare*.

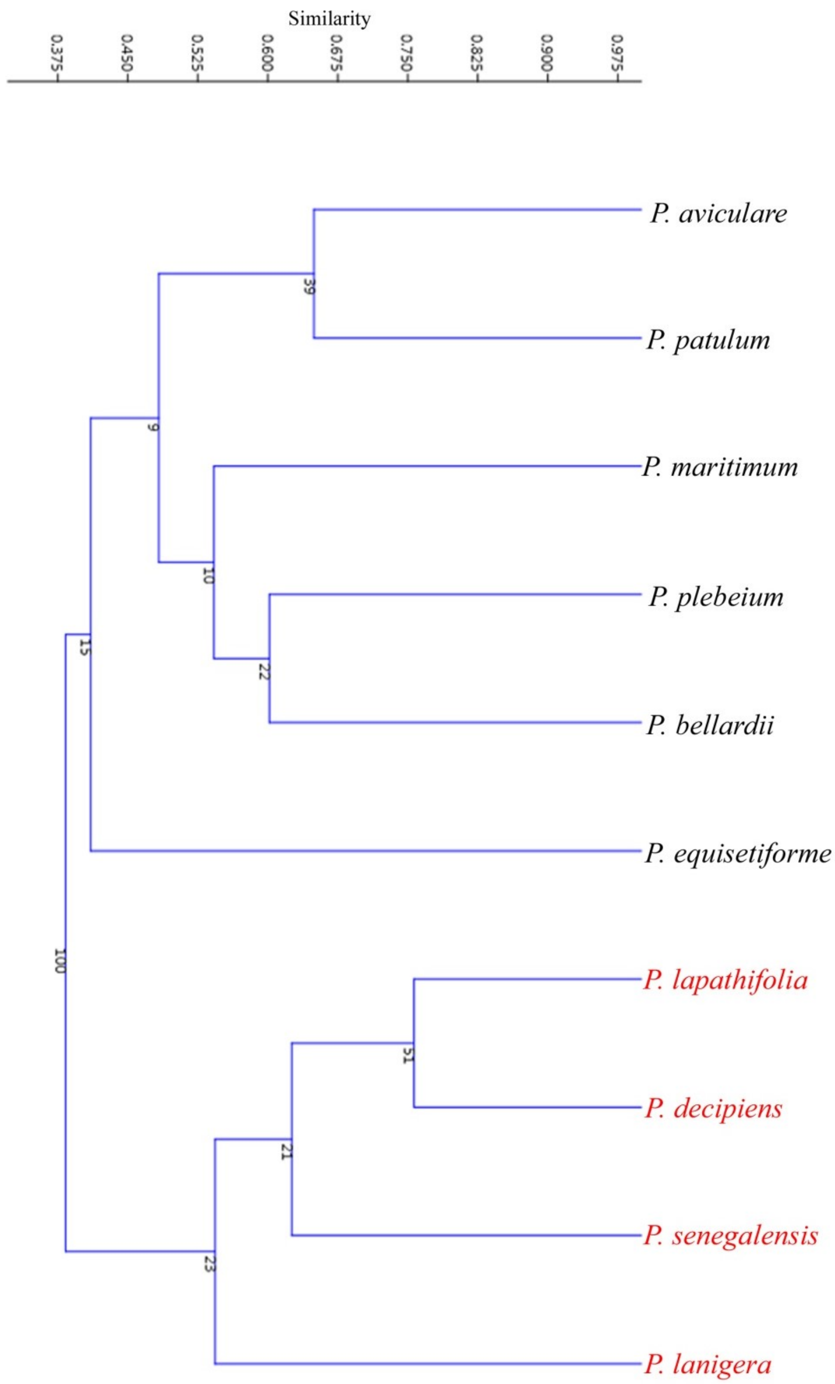

Figure 1. UPGMA grouping of the examined species according to morphological traits

The present study tried to find a correlation among the investigated morphological characters, it has been found that as indicated in Figure 2, there are positive correlations between some of the morphological characters that reached to its maximum (more than 0,66) in stem strength *Vs*. leaf elevation, bark color *Vs*. texture and apex, stem branching *Vs*. flower color, leaves texture *Vs*. leaf margin and apex, leaf margin *Vs*. leaf apex and perianth tube, ochrea color *Vs*. perianth tube. while there are negative correlations between some of the morphological characters that reached to its maximum (less than 0,66) in strength *Vs*. ochrea and nutlet color, bark color *Vs*. flowers and stamens number, leaves duration *Vs*. flowers number, ochrea shape *Vs*. nutlet shape. nutlet color *Vs*. nutlet shape.

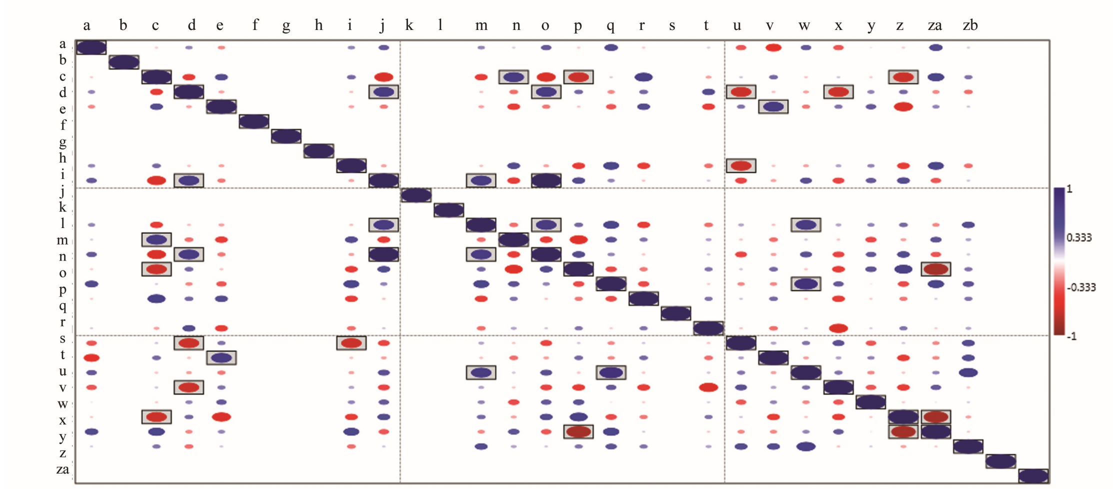

Figure 2. Correlation among the examined morphological traits of the taxa under study.
a. Life cycle, b. Habit, c. Strength, d. Bark colour, e. Stem branching, f. Stem colour, g. Appearence, h. Leaf composition, i. Leaf duration, j. Texture, k. Base, l. Shape, m. Margin, n. Elevation, o. Apex, p. Ochrea, q. Ochrea colour, r. Inflorescence, s. Flower, t. Pedicel, u. Number, v. Colour, w. Stamnes no., x. Style, y. Nutlet, z. Shape, za. Surface, zb. Fruit wing.

The principal component analysis (PCA) clarified that, the percentage of explained variances reached 27.87% in relation to the first component PC1 and 17.48% due to PC2 (Figure 3). From the loadings plot of PC1 as the major shareholder (Figure 4), it has been positively correlated with some morphological characters that reached to its maximum value in ochrea (0.40), and nutlet (0.37) while it has been negatively correlated with plant strength (-0.41) and shape of nutlet (-0.34). PCA ordination that are based on the examined morphological traits of the species under study are displayed in figure (5). The most distant and closest species among the taxa under study are identified. *P. maritimum* and *P. lanigera* are high distantly related taxa (percentage of similarity: 0.17), *P. maritimum* and *P. equisetiforme* are high closely related taxa (similarity: 75%). The length of the arrow is directly proportional to the variability in the two components, the very short arrow for example bark color indicates that the first two components contains no information about this component with loading score 0.15, while the loading score of the longest arrow representing strength reached 0.41. The angle between two arrows clarifies the correlation; the acute angle expresses positive correlation, the right angle expresses no correlation, while the obtuse angle implies negative correlation.

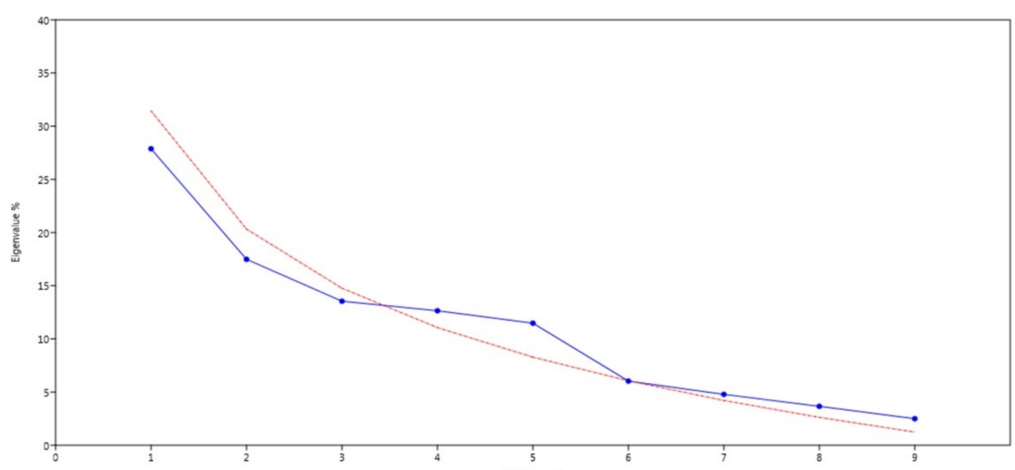

Figure 3. Scree plot indicating the percentage of explained variances *Vs.* principal components.

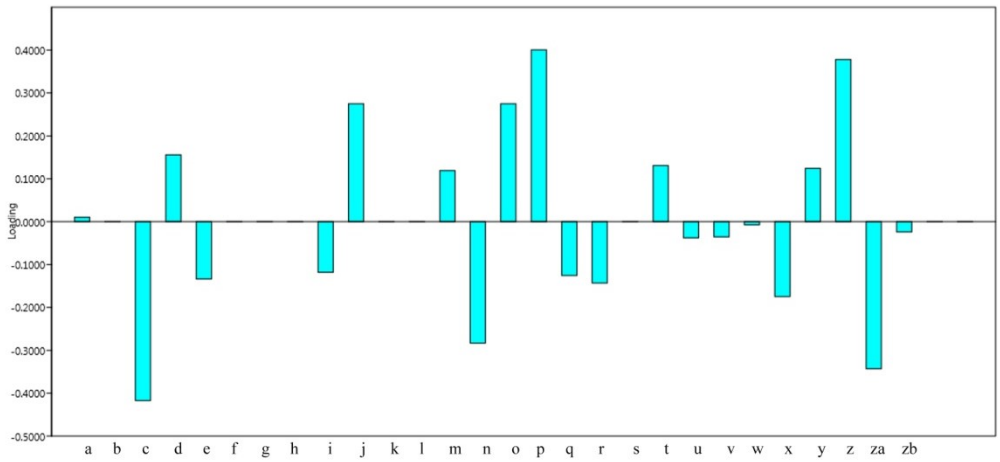

Figure 4. Loadings of morphological characters according to the first principal component (PC1).
a. Life cycle, b. Habit, c. Strength, d. Bark colour, e. Stem branching, f. Stem colour, g. Appearence, h. Leaf composition, i. Leaf duration, j. Texture, k. Base, l. Shape, m. Margin, n. Elevation, o. Apex, p. Ochrea, q. Ochrea colour, r. Inflorescence, s. Flower, t. Pedicel, u. Number, v. Colour, w. Stamnes no., x. Style, y. Nutlet, z. Shape, za. Surface, zb. Fruit wing.

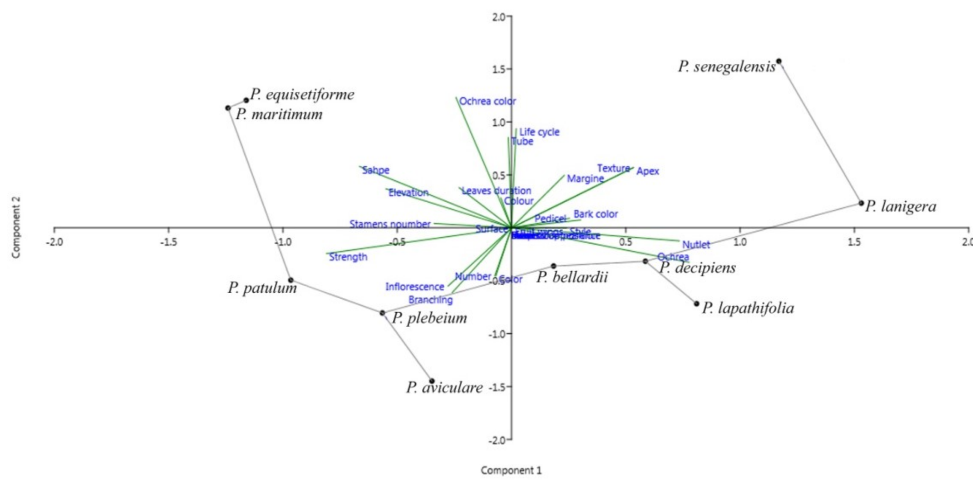

Figure 5. Principal component analysis of the species under study using morphological characteristics, indicating minimum spanning tree and biplot.

Discussion

From a phenetic perspective, the examined taxa of *Polygonum* are clustered together as a single phenetic group away from the group of *Persicaria*, this is in accord with some authors that recognized different genera within *Polygonum* and divided it into several genera; *Persicaria* was one of them Jaretzky (1925); Hedberg (1946); Mozaffarian (2012); Tantawy et al. (2020). In addition, Haraldson (1978) and Brandbyge (1993) suggested dividing *Polygonum s.l.* into Polygoneae and Persicarieae.

Concerning the correlation between some of the morphological characters to investigate the mutuality between these characters that strongly influences the quality of character matrix. When two characters are highly reliant on one another, we can determine the missing character's state based on the other's observed state. Yu et al. (2021). There is no common morphological element that can digitize the morphology of ancient creatures into sequences, in contrast to DNA or protein sequences that are encoded by set letters (four nucleotides and twenty amino acids).

Creating morphological character matrices, which include different OTUs and characters, is a useful and likely the most used method of converting morphology into sequences. Different OTUs are rated in different states, often 0 and 1, for distinct features according on their morphology. Yu et al. (2021). Shannon (1948) indicated that information is the lowering of uncertainty, If a trait is scored the same among OTUs in a group, the data given by this trait should be 0 because it does not lower any uncertainty.

The positive correlation between the investigated morphological characters reached to its maximum (more than 66%) between some characters indicating these characters can be used to offer guidance on how to divide modules in systematic research and deal with incomplete specimens. Yu et al. (2021).

PCA can be useful in the characters variability Ogwu and Osawaru (2016). PCA is used in multivariate statistical methods for biological patterns investigation and models based on large sets of correlated variables Marramà and Kriwet (2017). This method solve taxonomic issues in Botany Csiky et al. (2010). The morphology of Ochrea and nutlet can be considered as a strong support for the segregation of *Polygonum* from *Persicaria* Agrwal and Saxena (2012).

Conclusion

It is determined that the selected morphological traits were crucial for distinguishing species. While the first two main components accounted for little less than half of all morphological variants (45.35%), suggesting that the morphological traits displayed some degree of high variability that is helpful for discriminating, and these traits (ochrea, nutlet and plant strength) draw the phenetic relationships within *Polygonum* and *Persicaria*. Authors recommend the use of molecular data in future to validate the morphological segregation between the two studied genera by using more species.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contribution Statement

Conceptualization, U.K.A.; methodology, U.K.A. S.A.A.M., M.M.H.; validation, S.A.A.M., M.M.H.; investigation, U.K.A. S.A.A.M., M.M.H.; data curation, U.K.A. S.A.A.M., M.M.H.; writing—original draft preparation, U.K.A.; writing— review and editing, U.K.A. S.A.A.M., M.M.H.; All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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