

Morphological Variation in *Polygonum setaceum* (Polygonaceae)

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여귀과 식물 *Polygonum setaceum*의 형태적 변이

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ABSTRACT

Patterns of morphological variation in *Polygonum setaceum* Baldwin ex Elliott are examined, and the taxonomic significance of the varieties recognized by Fernald is reevaluated. The diagnostic characters used to differentiate the varieties in *P. setaceum* demonstrate virtually continuous variation, and broad geographic intergradation is recognized. Principal components analyses of major morphological characters also fail to separate the varieties. These results strongly suggest that recognition of var. *setaceum*, var. *interjectum*, and var. *tonsum* by Fernald is unwarranted.

INTRODUCTION

Polygonum L. (Polygonaceae) is a taxonomically difficult, highly variable genus of about 300 species. *Polygonum setaceum* Baldwin ex Elliott is endemic to eastern North America, and ranges from northern New York to Florida, and westward to coastal Texas (Fig. 1). The species usually occupies moist or swampy habitats, including margins of ponds, lakes, and swampy forests. The species is distinguished from its close relative, *P. hydroiperoides* Michaux, by its chromosome number (McDonald, 1980), broadly lanceolate leaves, and moderately to densely pubescent ocreae with long spreading hairs. In addition, an experimental hybridization study (McDonald, 1980) revealed that these two species were reproductively isolated.

As in many other species of *Polygonum*, *P. setaceum* is highly variable in many morphological characters, including pubescence. Leaf pubescence, especially, is extremely variable; from densely pubescent on both surfaces to completely glabrous. Fernald (1938) first noted the variation in leaf pubescence in the species, and formally recognized three varieties (var. *setaceum*, var. *interjectum* Fern., and var. *tonsum* Fern.), mainly on the basis of differences in length and density of hairs on leaf surfaces

(Table 1). According to Fernald (1938), the variation in these characters is geographically correlated, and the three varieties occupy specific ranges: (1) var. *setaceum*, from southeastern Virginia to Florida and Texas; (2) var. *interjectum*, from northern New York and Massachusetts to the outer Piedmont of Virginia; (3) var. *tonsum*, in southeastern Virginia and in Oklahoma.

Preliminary investigation on this species, however, indicated that the morphological distinction between var. *setaceum* and var. *interjectum* is not sharp, and intermediates between the two occur throughout the range of distribution. In addition, Mitchell (1968, 1971, 1976) demonstrated the induction of glabrous forms in some North American species of *Polygonum* when plants grow in contact with water, and it is suggested by Mitchell and Dean (1978) that the glabrous var. *tonsum* is merely a phenotypic modification of pubescent forms.

The objective of this study is to examine patterns of morphological variation in this species, and to reevaluate the taxonomic significance of the varieties recognized by Fernald.

MATERIALS AND METHODS

Data used in this study were collected from the herba-

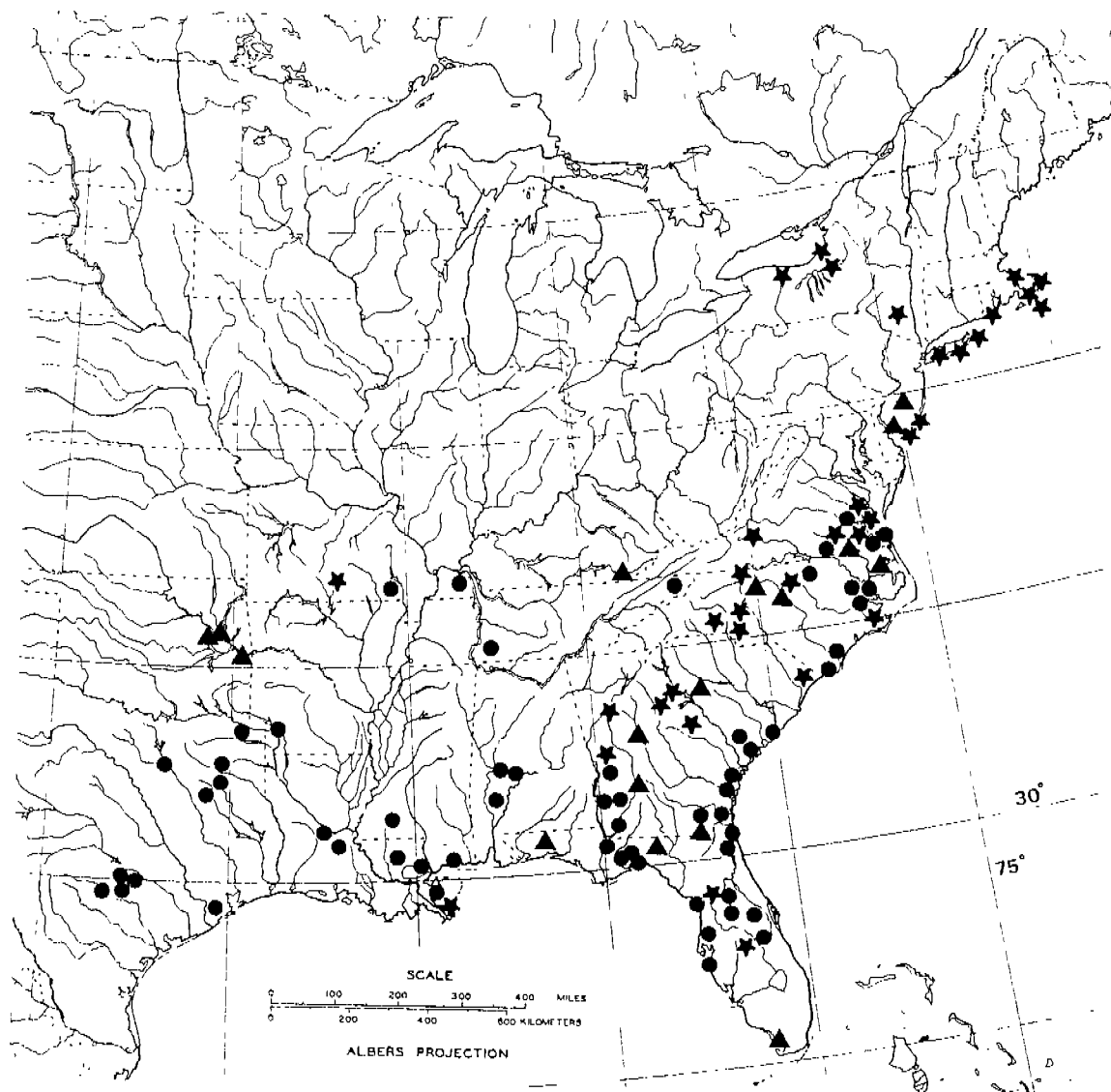


Fig. 1. Distribution of *Polygonum setaceum*. Some localities in very close proximity to each other are represented by a single symbol. Closed circles represent collections referable to var. *setaceum*; stars, var. *interjectum*; and triangles, var. *tonsum*.

rium specimens borrowed from the following herbaria: A, BH, CU, DOV, DUKE, F, GH, ILL, IND, MO, NCSC, NEB, NEBC, NY, PH, and TEX. Approximately 240 specimens, including types, were examined to determine the geographical range and morphological variation of the species. Specimens were identified primarily by the characters used by Fernald (Table 1). A list of specimens used for this study is available from the author.

After removal of duplicates, 123 specimens, including

65 of var. *setaceum*, 42 of var. *interjectum*, and 16 of var. *tonsum*, were used for morphological analyses. Of these, 107 pubescent specimens referable to var. *setaceum* or var. *interjectum* were scored for four leaf pubescent characters (Table 2; characters 1-4). Then a subset of 77 specimens, including 38 of var. *setaceum*, 26 of var. *interjectum*, and 13 of var. *tonsum*, were measured for 19 additional vegetative, inflorescence, and fruit characters (Table 2; characters 5-23) to examine overall patterns

Table 1. Varieties of *Polygonum setaceum* and their distinguishing characters recognized by Fernald (1938)

Varieties	Leaf		Hair length (Upper surface; mm)
	Upper surface	Lower surface	
<i>setaceum</i>	densely strigose	densely strigose	0.8-1.5
<i>interjectum</i>	strigose	strigose to glabrous	0.2-0.5
<i>tonsum</i>	glabrous	glabrous	-

of morphological variation in the species; 46 specimens were excluded from the measurements, because these characters could not be reliably measured in these specimens due to the condition of material or lack of appropriate organs.

For leaf characters, a large, mature leaf at the sixth or seventh node below the inflorescence was used for measurements. Length and density of leaf and ocrea hairs were measured using an ocular micrometer and a mesh-micrometer, respectively, under a stereoscopic microscope. Measurements were made from the identical locations on organs in each specimen to reduce variation. For inflorescence and fruit characters, one to three fully matured inflorescences were selected for measurements. Except characters 5-10, and 14 (Table 2), five to eight measurements were made for each character in each specimen, and an average of the measurements was used for the analyses.

To describe better the patterns of morphological variation in the species, data sets derived from the above measurements were subjected to principal components analysis. The principal components analysis was performed in two stages; (1) analysis of pubescent individuals referable to var. *setaceum* or var. *interjectum* using four leaf pubescence characters (Table 2; characters 1-4), and (2) analysis of individuals of all three varieties using 19 vegetative, inflorescence, and fruit characters (Table 2; characters 5-23). The analyses were carried out using Statistical Analysis System (SAS Institute; Release 6.03) on an IBM PC. Data matrices used for the analyses are available from the author upon request.

RESULTS AND DISCUSSION

Although *P. setaceum* shows considerable variation in length and density of leaf hairs, all pubescent individuals

Table 2. Characters used in analyses of morphological variation in *Polygonum setaceum*

Leaf:
1. Upper surface hair length (mm)
2. Upper surface hair density (number per 5 mm ²)
3. Lower surface hair length (mm)
4. Lower surface hair density (number per 5 mm ²)
5. Blade length (cm)
6. Blade width at widest point (cm)
7. Blade width/blade length (character 6/character 5)
8. Position of the widest point of the blade (length from the base to the point of maximum width/blade length)
9. Petiole length (mm)
Ocrea:
10. Ocrea length (cm)
11. Marginal cilia length (cm)
12. Hair length (mm)
13. Hair density (number per 5 mm ²)
Inflorescence:
14. Inflorescence length (cm)
15. Compactness of inflorescence (number of flower fascicles per 2 cm at middle portion)
16. Number of flowers per flower fascicle
17. Bract length (mm)
18. Bract marginal cilia length (mm)
19. Pedicel length (mm)
20. Perianth length (mm)
21. Degree of perianth cleft (length from the base of perianth to the point of cleft/perianth length)
Fruit:
22. Achene length (mm)
23. Achene width (mm)

referable to var. *setaceum* or var. *interjectum* develop the same type of hair. Plants of both varieties develop relatively stiff, simple, multicellular hairs usually on both surfaces of leaves, which differ only in overall length.

Fernald (1938) separated var. *interjectum* from var. *setaceum* primarily on the basis of leaf hair length and density (Table 1). According to Fernald, plants of var. *setaceum* are "copiously long-strigose" usually on both leaf surfaces with the hair length ranging from 0.8 mm to 1.5 mm, whereas those of var. *interjectum* are "short-strigose" with the hair length ranging from 0.2 mm to 0.5 mm. However, measurements from pubescent individuals referable to var. *setaceum* or var. *interjectum* show that leaf hair length varies continuously from 0.34 mm to 1.51 mm on upper surfaces and from 0.23 mm to 0.96 mm on lower surfaces, with no absolute discontinuities

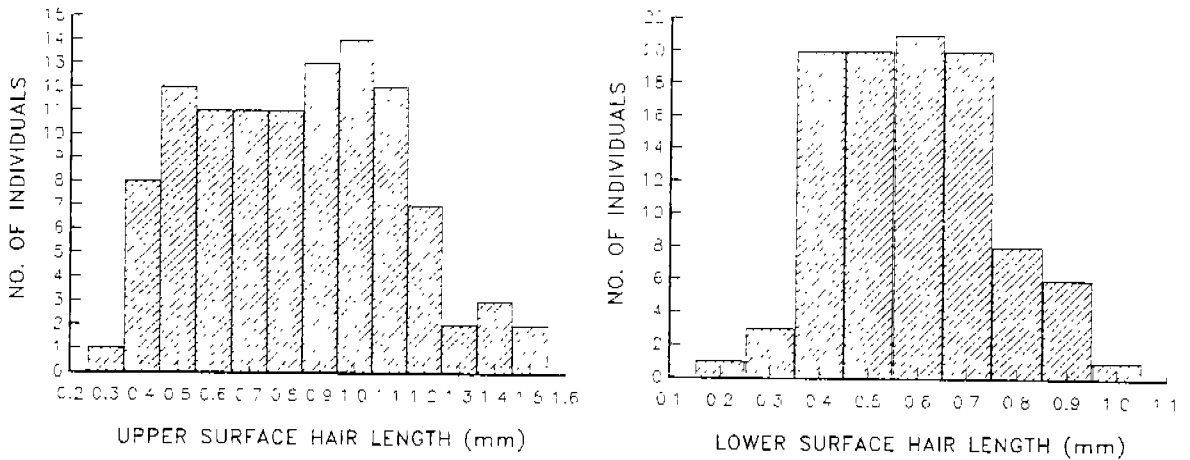


Fig. 2. Histograms showing distribution of leaf hair lengths in *Polygonum setaceum*. Glabrous individuals (var. *tonsum*) are not included.

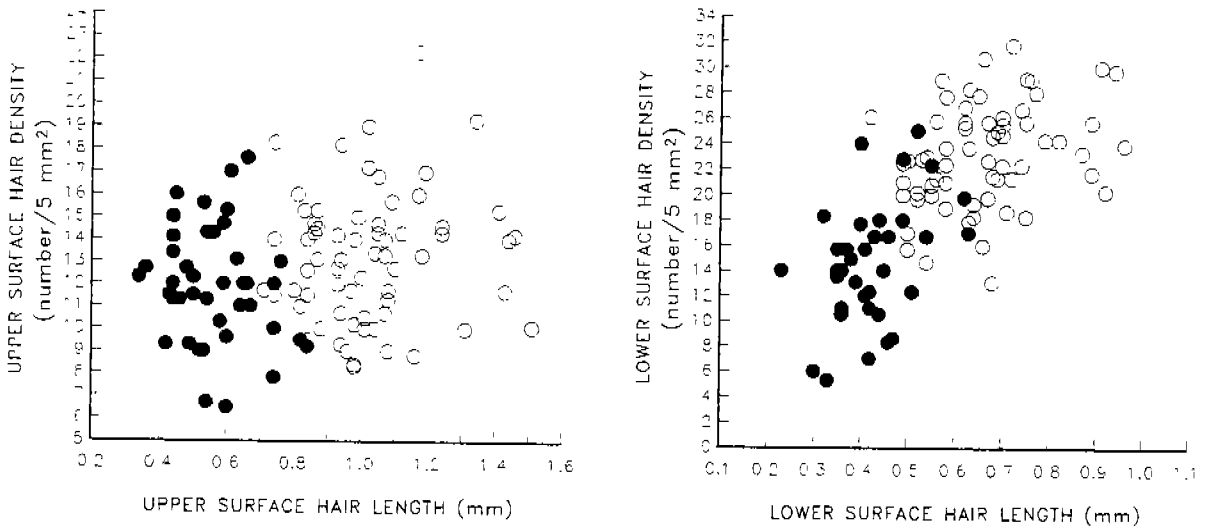


Fig. 3. Scatter diagrams of leaf hair length versus density in var. *setaceum* (open circles) and var. *interjectum* (closed circles). Some individuals are hidden due to the same values.

or strong bimodality (Fig. 2). In addition, the scatter plots of hair length and density on both surfaces suggest only a single taxon, and no clear gap exists between the two varieties in these characters (Fig. 3).

To check the extent of geographical differentiation in leaf hair length mentioned by Fernald (1938), pubescent individuals from across its range were sorted geographically (by states), and examined for the means and ranges of upper and lower surface hair lengths (Fig. 4). In general, plants from the northern extreme of its range, which comprises New York and Massachusetts, tend to bear relatively short hairs (0.44-0.76 mm long) usually on both

surfaces as compared to those from the southern extreme of its range in Texas. In the latter region, a high proportion of collections develops relatively long hairs, ranging from 0.81 mm to 1.51 mm long on upper surfaces and 0.55 mm to 0.96 mm long on lower surfaces. In addition, they tend to be more pubescent on both surfaces of the leaves. However, a considerable overlap occurs in the ranges of hair length on both surfaces among these geographically delimited samples, and there is no clear geographic partitioning of variation in this character. Although the variation in leaf hair length within geographical areas is extensive, the mean hair length on both sur-

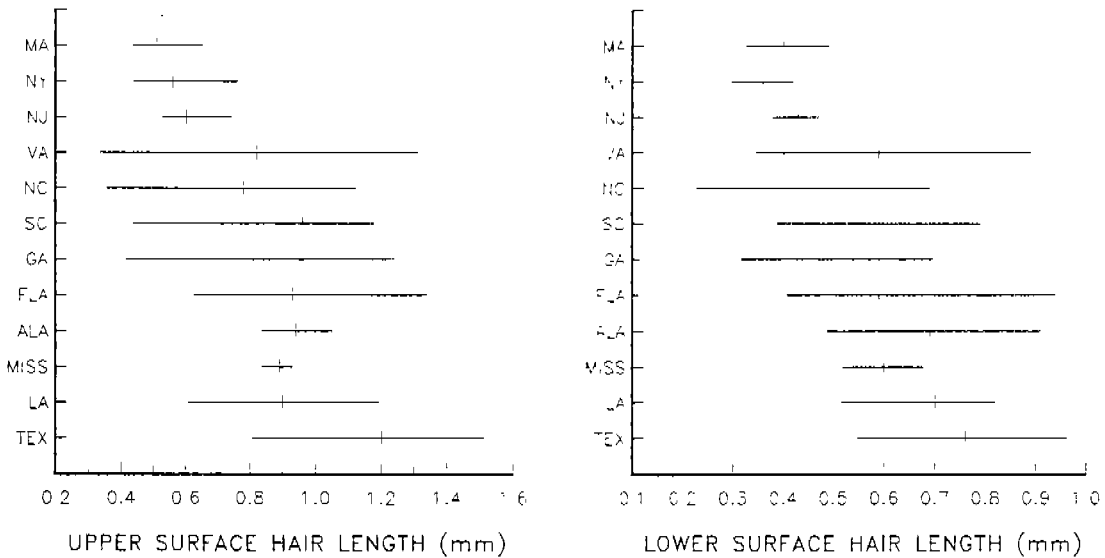


Fig. 4. Variation in leaf hair lengths in pubescent individuals of *Polygonum setaceum* sorted geographically (by states). States are arranged approximately from north to south. States with one or two collections are not plotted. Vertical lines represent the mean.

Table 3. Loadings of the first two principal components for the four leaf pubescence characters from the analysis of pubescent individuals of *Polygonum setaceum*

Characters	Component	
	1	2
Upper surface hair length	0.546	-0.195
Upper surface hair density	0.234	0.958
Lower surface hair length	0.580	-0.211
Lower surface hair density	0.557	0.008
Eigenvalue	2.624	0.925
Cumulative % of Eigenvalues	65.6	88.7

faces, in general, gradually increases from north to south, and broad geographic intergradation can be recognized (Fig. 4). Similar patterns of geographical variation in leaf pubescence were also observed in other North American species of *Polygonum* (Park, 1987, 1988).

To better evaluate the degree of distinctness of var. *setaceum* and var. *interjectum* with regard to the variation in leaf pubescence, measurements of four leaf pubescence characters (Table 2; characters 1-4) from the same individuals were analyzed using principal components analysis. Results of the analysis are given in Table 3, and an ordination of individual specimens projected on the first two principal components (axes) is shown in

Fig. 5. The first two principal components accounted for 88.7 percent of the total variance (Table 3). The first principal component was weighted heavily for upper surface hair length, lower surface hair length, and lower surface hair density, whereas the second component was weighted heavily for upper surface hair density (Table 3). However, neither components clearly separate var. *interjectum* from var. *setaceum*; only collections from northern New York appear as a separate cluster on the first component (Fig. 5). The distinctness of these individuals with regard to the first component is probably due to their low values in lower surface hair density. Leaves of these individuals are almost glabrous to sparsely pubescent on lower surfaces, whereas those from other areas referable to var. *interjectum* are usually moderately pubescent on both surfaces. However, these individuals are not consistently distinguishable by any characters other than lower surface hair density, which appears to be frequently influenced by developmental and environmental conditions (Mitchell, 1968, 1971, 1976). Therefore, it is not considered here a sufficient basis for assigning a formal taxonomic rank.

To evaluate the distinctness of the varieties in the species with regard to other morphological features excluding leaf pubescence characters, measurements of 19 vegetative, inflorescence, and fruit characters (Table 2; characters 5-23) were analyzed by principal components ana-

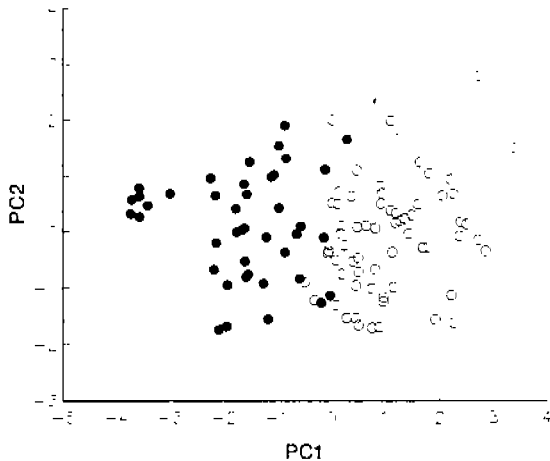


Fig. 5. Principal components analysis of pubescent individuals of *Polygonum setaceum* using four leaf pubescent characters (cf. Table 2). Glabrous individuals (var. *tonsum*) were excluded from the analysis. Some individuals are hidden due to the same values. Symbols: Open circles=var. *setaceum*. Closed circles=var. *interjectum*.

lysis. In this analysis, glabrous individuals referable to var. *tonsum* were also included to examine whether var. *tonsum* is distinct on the basis of any morphological features other than leaf pubescence. The first three principal components accounted for 22.7, 12.2 and 10.3 percent of the total variance, respectively (Table 4). Subsequent components contributed less than 8 percent each. The plots of individual specimens projected on the combinations of the first three components are shown in Fig. 6. Characters correlated with the first component were petiole length, ocrea length, ocrea hair length, bract length, and achene length. Those correlated with the second component included leaf length and width, perianth length, and achene width. Characters related to the third component included position of the widest point of the leaf blade, inflorescence length, pedicel length, and compactness of inflorescence (Table 4). However, the result of the analysis showed the almost complete overlap among these three varieties, and failed to differentiate them (Fig. 6). Especially noteworthy are the positions of individuals of var. *tonsum* in the principal components plots. In Fig. 6, individuals of var. *tonsum* are interspersed among those of vars. *setaceum* and *interjectum*, reflecting the absence of diagnostic characters other than leaf pubescence. Also, this form occurs sporadically throughout the range of the species (Fig. 1). These observations strongly support the view (Mitchell and Dean, 1978)

Table 4. Loadings of the first three principal components for 19 vegetative, inflorescence, and fruit characters from the analysis of *Polygonum setaceum*

Character number*	Component		
	1	2	3
5	0.213	0.479	-0.037
6	0.223	0.481	-0.008
7	0.046	0.066	0.051
8	0.152	0.007	0.355
9	0.290	0.268	0.017
10	0.314	0.158	0.260
11	-0.101	0.185	0.108
12	-0.325	0.079	0.065
13	-0.318	-0.061	-0.098
14	0.123	0.097	-0.439
15	-0.016	0.056	0.516
16	-0.051	0.192	-0.277
17	0.291	-0.070	0.064
18	-0.265	0.095	0.116
19	0.243	-0.149	-0.412
20	0.215	-0.407	0.011
21	-0.071	-0.089	0.203
22	0.359	-0.214	0.039
23	0.259	-0.299	0.102
Eigenvalue	4.309	2.321	1.951
Cumulative % of Eigenvalues	22.7	34.9	45.2

*Character numbers correspond to those in Table 2.

that the glabrous form (var. *tonsum*) is merely a phenotypic modification of pubescent forms.

CONCLUSION

Leaf pubescence characters considered by Fernald as diagnostic for varieties in *P. setaceum* demonstrate a high amount of variability and fail to delineate the varieties. In pubescent individuals, the leaf pubescence characters show virtually continuous variation without gaps or strong bimodality (Figs. 2 and 3), and broad geographic intergradation is recognized (Fig. 4). Also, there is no geographic integrity to var. *interjectum*; its distribution virtually parallels that of var. *setaceum* (Fig. 1). These results are also supported by principal components analysis of leaf pubescence characters, which indicated that var. *interjectum* was not clearly distinct from var. *setaceum* (Fig. 5). In addition, failure to distinguish var. *setaceum*, var. *interjectum*, and var. *tonsum* by principal components analysis (Fig. 6) suggests lack of any morphological characters

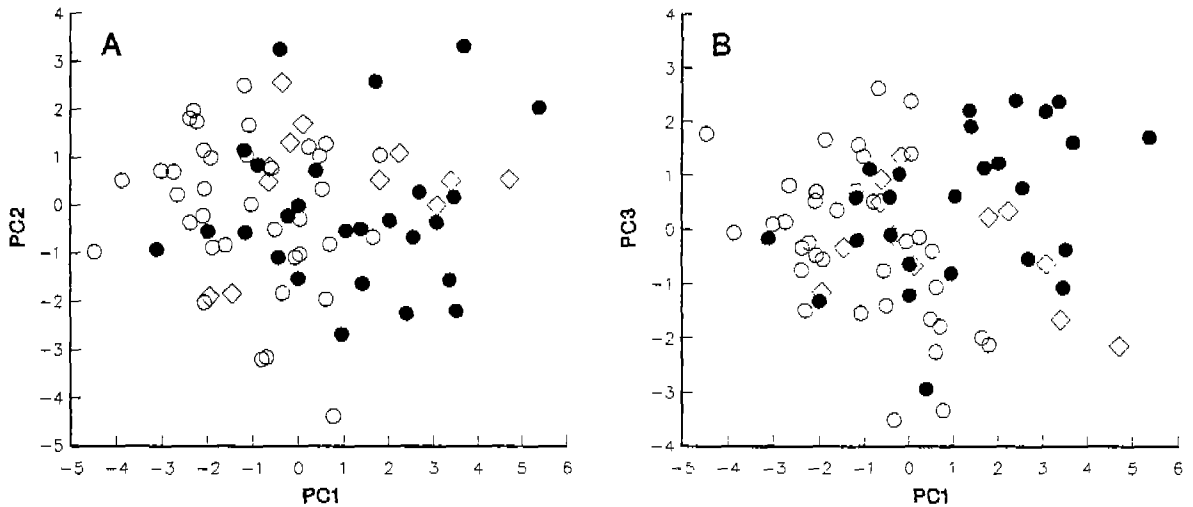


Fig. 6. Principal components analysis of *Polygonum setaceum* using 19 vegetative, inflorescence, and fruit characters (cf. Table 2). All varieties were included in the analysis. Some individuals are hidden due to the same values. A. component 1 vs. component 2. B. component 1 vs. component 3. Symbols: Open circles=*var. setaceum*. Closed circles=*var. interjectum*. Diamonds=*var. tonsum*.

correlating with them. These results indicate that recognition of *var. setaceum*, *var. interjectum*, and *var. tonsum* by Fernald based on quantitative differences in leaf pubescence is unwarranted, and the varieties should not be recognized as taxonomically distinct.

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적 요

Polygonum setaceum Baldwin ex Elliot의 형태적 변이 양상을 분석하여 Fernald에 의해 본종에 설정된 3 변종의 분류학적 타당성을 검토하였다. 이들 3 변종의 주요 형태적 형질을 측정 분석한 결과, 이들을 구분하는데 사용되어 왔던 대부분의 주요 식별형질들은 연속적인 변이를 나타

내었으며, Fernald에 의해 본종에 설정된 3 변종은 분류학적 타당성이 없는 것으로 판명되었다.

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