Wydział Biologii
Uniwersytetu Gdańskiego

mgr Adrianna Maria Kosiróg-Ceynowa

Zastosowanie mikromorfologii, metod morfometrycznych oraz molekularnych w identyfikacji wybranych gatunków rodzaju *Alchemilla* L. (Rosaceae)

Application of micromorphological, morphometric and molecular methods in the identification of selected species of *Alchemilla* L. (Rosaceae)

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Promotor: prof. dr hab. Dariusz L. Szlachetko
Promotor pomocniczy: dr Sławomir Nowak
Katedra Taksonomii Roślin i Ochrony Przyrody, Wydział Biologii,
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Pragnę podziękować wszystkim,
którzy byli przy mnie podczas powstawania tej rozprawy.
Osobom, które dzieliły się ze mną wiedzą,
doświadczeniem oraz pomagały w realizacji badań.
Szczególne podziękowania kieruję do tych,
którzy wspierali mnie w codziennych obowiązkach,
dodawali otuchy oraz motywowali do dalszej pracy.
Każda z nich miała swój udział w tym,
że mogłam doprowadzić tę pracę do końca.

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1. Streszczenie

Tematem niniejszej rozprawy doktorskiej jest zastosowanie mikromorfologii, metod morfometrycznych oraz molekularnych w identyfikacji wybranych gatunków rodzaju *Alchemilla* L. (Rosaceae).

Rodzaj *Alchemilla* należy do grup roślin szczególnie trudnych pod względem taksonomicznym. Liczne gatunki są morfologicznie bardzo podobne do siebie, a nakładanie się tradycyjnie wykorzystywanych cech diagnostycznych utrudnia jednoznaczną identyfikację jego przedstawicieli. Dodatkowym utrudnieniem są złożone procesy biologiczne i ewolucyjne, w tym apomiksja, poliploidia oraz potencjalna hybrydyzacja. Pomimo dotychczasowych badań nadal potrzebna jest ocena, które źródła danych rzeczywiście wspomagają różnicowanie taksonów i jakie są ograniczenia ich wartości diagnostycznej.

W ramach celu głównego podjęto próbę określenia zróżnicowania morfometrycznego, mikromorfologicznego oraz molekularnego wybranych gatunków rodzaju *Alchemilla* L. (Rosaceae) jako potencjalnego źródła informacji taksonomicznych przy oznaczaniu badanych taksonów. Badania przeprowadzono w ramach trzech części obejmujących nieco odmienny materiał gatunkowy i okazowy. Poszczególne części dotyczyły morfometrii i mikromorfologii owoców, morfometrii liści oraz analiz mikromorfologicznych i molekularnych. W badaniach zastosowano metody morfometryczne, obejmujące współczynniki kształtu, oraz metody statystyczne, w tym PCA, PERMANOVA, PERMDISP i NMDS, metody mikromorfologiczne wykorzystujące technikę skaningowej mikroskopii elektronowej oraz metody molekularne bazujące na analizach sieciowych i rekonstrukcjach filogenetycznych. Uzupełnieniem jednej z części badań była cytometryczna ocena zawartości jądrowego DNA.

Przeprowadzone analizy wykazały, że wartość diagnostyczna badanych cech była zróżnicowana. Morfometria owoców wykazała znaczne nakładanie się zakresów zmienności pomiędzy gatunkami. Natomiast ich cechy mikromorfologiczne, szczególnie związane ze strukturą powierzchni i morfologią komórek epidermy, dostarczyły bardziej użytecznych informacji taksonomicznych. Podobnie morfometria liści ujawniła zróżnicowanie pomiędzy częścią badanych taksonów, jednak o ograniczonej wartości przy identyfikacji pojedynczych okazów. Całościowo nie pozwoliła na ich jednoznaczne rozdzielenie ani na pewne przyporządkowanie

okazów oznaczonych jako *Alchemilla* sp. Analizy makro- i mikromorfologiczne liści wykazały zróżnicowanie względnej wielkości ząbka szczytowego oraz występowania i rozmieszczenia trichomów. Również w tym przypadku nie stwierdzono zestawu cech jednoznacznie odpowiadającego poszczególnym gatunkom. Spośród badanych markerów molekularnych największą wartość informacyjną wykazał jądrowy region ITS, natomiast markery plastydowe *matK*, *rpoC1* i *trnH-psbA* charakteryzowały się mniejszą zdolnością różnicowania badanych taksonów. Analizy cytometryczne wykazały natomiast niewielkie zróżnicowanie zawartości jądrowego DNA i znaczne nakładanie się wartości pomiędzy taksonami.

Uzyskane wyniki wskazują, że zastosowane metody powinny być traktowane jako komplementarne, a nie niezależne źródła informacji. Rozpatrywane samodzielnie, nie pozwalały na jednoznaczną identyfikację wszystkich badanych gatunków. W badanym materiale wybrane cechy powierzchni niełupek wykazały większy potencjał różnicujący niż ich kształt, jednak ich przydatność do samodzielnej identyfikacji wymaga dalszej weryfikacji. Zestawienie danych morfometrycznych, mikromorfologicznych, molekularnych oraz cytometrycznych pozwala na pełniejszą ocenę zróżnicowania badanych taksonów i wskazuje na znaczenie podejścia integracyjnego w badaniach taksonomicznych rodzaju *Alchemilla*.

2. English summary

The subject of this doctoral thesis is the application of micromorphological, morphometric and molecular methods in the identification of selected species of the genus *Alchemilla* L. (Rosaceae).

The genus *Alchemilla* comprises a taxonomically challenging group of plants. Numerous species are morphologically very similar, and the overlap of traditionally used diagnostic characters makes unambiguous species identification difficult. Additional complexity results from biological and evolutionary processes, including apomixis, polyploidy and potential hybridisation. Despite previous research, there is still a need to assess which sources of data can support species differentiation and what limitations affect their diagnostic value.

The main objective of the study was to assess morphometric, micromorphological and molecular variation among selected species of *Alchemilla* L. (Rosaceae) and to evaluate their potential taxonomic utility in species identification. The research comprised three parts based on partly different sets of species and specimens. These focused on achene morphometry and micromorphology, leaf morphometry, and leaf micromorphology combined with molecular analyses. Morphometric analyses included shape descriptors and statistical analyses, including PCA, PERMANOVA, PERMDISP and NMDS. Micromorphological characters were examined using scanning electron microscopy, whereas molecular differentiation was assessed using phylogenetic and network analyses. One part of the study was additionally supplemented by an assessment of nuclear DNA content using flow cytometry.

The analyses showed that the diagnostic value of the investigated characters varied among the different sources of data. Achene morphometry revealed considerable overlap among species, indicating limited taxonomic utility of achene shape. In contrast, achene micromorphological characters, particularly those related to surface ornamentation and epidermal cell morphology, showed greater diagnostic potential. Leaf morphometric analyses also revealed differentiation among some of the taxa studied, although considerable overlap limited their usefulness for specimen identification. Overall, leaf morphometry did not allow unambiguous separation of the morphologically identified species or reliable assignment of specimens identified as *Alchemilla* sp. Macro- and micromorphological analyses of leaves revealed variation

in the relative size of the apical tooth and in trichome abundance and distribution. However, none of the observed combinations of characters was restricted to a single morphologically identified species.

Among the molecular markers analysed, the nuclear ITS region contained the highest proportion of variable and parsimony-informative sites and provided the most informative phylogenetic reconstruction. In contrast, the plastid markers *matK*, *rpoC1* and *trnH-psbA* showed more limited discriminatory power. Neither phylogenetic nor network analyses provided consistent species-level separation of the investigated taxa. Nuclear DNA content showed relatively limited variation and considerable overlap among taxa.

Overall, none of the investigated datasets alone provided unambiguous identification of all the species studied. Selected achene micromorphological characters showed greater diagnostic potential than achene shape, although their taxonomic utility requires further evaluation. Morphometric, micromorphological, molecular and cytometric data should therefore be regarded as complementary sources of taxonomic information. Their combined interpretation provides a more comprehensive assessment of variation among the investigated taxa and supports the use of an integrative approach in taxonomic studies of the genus *Alchemilla*.

3. Wprowadzenie

Rodzaj *Alchemilla* L. należy do rodziny *Rosaceae* Juss., podrodziny *Rosoideae* (Juss.) Arn., plemienia *Potentilleae* Sweet oraz podplemienia *Fragariinae* Torr. & A. Gray. Rodzaj został formalnie opisany w 1753 roku przez Karola Linneusza w „*Species Plantarum*" (Linnaeus, 1753). W zależności od ujęcia taksonomicznego szacuje się, że rodzaj ten obejmuje około 1000 gatunków na świecie, w tym 300-400 gatunków występujących w Europie (Gehrke et al., 2008; Shokatyari et al., 2022; Jakimiuk & Tomczyk, 2024). W Polsce wyróżnia się około 55-70 gatunków (Mirek et al., 2020). Rodzaj występuje głównie w Eurazji, a jego przedstawiciele są obecni również w górskich obszarach Afryki. W Europie szczególnie duże zróżnicowanie rodzaju związane jest z pasmami górskimi, m.in. Alpami, Tatrami oraz Karpatami (Kurtto et al., 2007; Pihu et al., 2009; Gehrke & Linder, 2009).

Przedstawiciele rodzaju *Alchemilla* są głównie wieloletnimi roślinami zielnymi o łodygach od pokładających się do wzniesionych oraz liściach odziomkowych i łodygowych (Li et al., 2003). Kwiaty są drobne, żółtozielone, obupłciowe, zwykle czterokrotne i pozbawione płatków korony (Faghir et al., 2017). Duże podobieństwo w silnie zredukowanej budowie kwiatów występuje również u blisko spokrewnionych *Aphanes* L. i *Lachemilla* (Focke) Rydb., które wraz z *Alchemilla* należą do podplemienia Fragariinae. Podobieństwa pomiędzy tymi grupami przyczyniały się do różnych ujęć ich granic taksonomicznych. Istotną rolę w uporządkowaniu systematyki rodzaju *Alchemilla* odegrał Sigurd E. Fröhner, który prowadził szeroko zakrojone badania nad jego europejskimi przedstawicielami. W 1975 roku opublikował krytyczne opracowanie europejskiej taksonomii rodzaju, natomiast w 1986 roku przedstawił jego podział wewnątrzrodzajowy; był również autorem rozbudowanych kluczy oraz charakterystyk taksonów (Fröhner, 1975, 1986, 1990).

Rozwój metod molekularnych umożliwił ponowne przeanalizowanie relacji pomiędzy *Alchemilla*, *Aphanes* i *Lachemilla*. Gehrke et al. (2008), na podstawie danych plastydowych i jądrowych, wykazali ich bliskie pokrewieństwo oraz zaproponowali szerokie ujęcie rodzaju *Alchemilla*, obejmujące również *Aphanes* i *Lachemilla*. Dodatkowym utrudnieniem w systematyce rodzaju było wyróżnianie coraz większej liczby wąsko ujmowanych gatunków i mikrogatunków, których granice morfologiczne często pozostawały niejednoznaczne (Gehrke et al., 2008; Pihu et al., 2009).

Problemy z jednoznacznym wyznaczaniem granic gatunkowych w rodzaju *Alchemilla* wynikają jednak nie tylko z dużej liczby wyróżnianych mikrogatunków, ale również ze specyficznych cech biologii i historii ewolucyjnej tego rodzaju. U wielu przedstawicieli występuje rozmnażanie apomiktyczne, przy czym nasiona rozwijają się bez zapłodnienia, natomiast wytwarzanie żywotnego pyłku jest silnie ograniczone lub nie występuje wcale (Czapik, 1996; Gehrke et al., 2008; Pihu et al., 2009; Dobeš et al., 2015). W konsekwencji uważa się, że rozmnażanie płciowe odgrywa jedynie ograniczoną rolę w wielu liniach rozwojowych. Niemniej jednak u niektórych mikrogatunków stwierdzono wytwarzanie przynajmniej częściowo żywotnego pyłku, co wskazuje, że sporadyczne rozmnażanie płciowe i hybrydyzacja mogą mieć miejsce (Pihu et al., 2009). Takie zdarzenia, w połączeniu z późniejszym utrwalaniem genotypów na drodze apomiksji, mogą przyczyniać się do powstawania i utrzymywania nowych linii (Gehrke et al., 2008; Sailer et al., 2016). Co więcej, częsta poliploidia, współwystępująca z apomiksją i możliwą hybrydyzacją, dodatkowo komplikuje interpretację relacji pomiędzy taksonami (Hayırlıoğlu-Ayaz & İnceer, 2006; Gehrke et al., 2008). Taka kombinacja procesów może sprzyjać powstawaniu i utrzymywaniu licznych, blisko spokrewnionych jednostek o niejednoznacznych granicach taksonomicznych.

Tradycyjne podejście morfologiczne pozostaje podstawą identyfikacji gatunków rodzaju *Alchemilla*, jednak jego zastosowanie jest często utrudnione ze względu na niewielkie różnice pomiędzy taksonami oraz nakładanie się cech diagnostycznych. Dotychczas przy oznaczaniu wykorzystywano kilka głównych grup cech dotyczących organów wegetatywnych i generatywnych (Sepp & Paal, 1998). W kluczach oraz opracowaniach taksonomicznych szczególne znaczenie przypisuje się jednak cechom organów wegetatywnych, w tym owłosieniu oraz cechom ząbkowania brzegów blaszek liściowych (McNeill et al., 2014; Frost-Olsen, 2016).

Liście stanowią jeden z głównych organów wegetatywnych wykorzystywanych w identyfikacji przedstawicieli rodzaju *Alchemilla*. Wyróżnia się liście odziomkowe oraz łodygowe, którym towarzyszą przylistki (McNeill et al., 2014). Przy identyfikacji szczególne znaczenie ma blaszka liści odziomkowych oraz występujące na niej struktury. Blaszka może mieć kształt od nerkowatego do kolistego i jest zwykle dłoniasto klapowana, często z 7-9(-11) klapami (Pihu et al., 2009; McNeill et al., 2014).

Do istotnych cech należą więc kształt i wymiary blaszki liściowej, liczba klap, głębokość wcięć między klapami oraz cechy ząbków (Sepp & Paal, 1998; Pihu et al., 2009; McNeill et al., 2014).

Istotne znaczenie mogą mieć również cechy ogonków liściowych oraz łodyg. Łodygi u przedstawicieli rodzaju mogą być pokładające się, podnoszące się lub wzniesione (Li et al., 2003; McNeill et al., 2014). W badaniach taksonomicznych dużą uwagę zwraca się również na owłosienie blaszek liściowych, ogonków liściowych i łodyg. Cechy te mogą różnić się obecnością lub brakiem włosków, ich zagęszczeniem oraz kierunkiem ułożenia i wykazują znaczenie taksonomiczne (Hayırlıoğlu-Ayaz & Beyazoğlu, 1997; Sepp & Paal, 1998; Faghir et al., 2014a, 2014b). Na poziomie mikromorfologicznym analizowane są również cechy epidermy oraz aparatów szparkowych.

Wśród organów generatywnych analizowanych u rodzaju *Alchemilla* istotne są przede wszystkim kwiaty oraz owoce. W przypadku kwiatów do cech wykazujących znaczenie w różnicowaniu gatunków należą m.in. kształt i długość działek kielicha oraz rozmieszczenie włosków na kielichu i szypułce (Faghir et al., 2017). Owocami przedstawicieli tego rodzaju są niełupki zamknięte w trwałym hypancjum. Do cech o potencjalnym znaczeniu taksonomicznym należą przede wszystkim mikrorzeźba powierzchni niełupek, kształt komórek epidermy oraz cechy ich ścian (Shokatyari et al., 2022). Cechy organów generatywnych były dotychczas stosunkowo rzadziej wykorzystywane w badaniach taksonomicznych rodzaju *Alchemilla* niż cechy organów wegetatywnych (Notov & Kusnetzova, 2004; Faghir et al., 2017; Shokatyari et al., 2022).

Pojedyncze cechy morfologiczne nie zawsze pozwalają jednak na jednoznaczne wyznaczenie granic pomiędzy blisko spokrewnionymi gatunkami. W przypadku rodzaju *Alchemilla* część mikrogatunków wykazuje znaczne podobieństwo morfologiczne, co może utrudniać ich identyfikację na podstawie pojedynczych cech (Sepp & Paal, 1998; Pihu et al., 2009). Niewielkie różnice między taksonami oraz możliwość przeoczenia części cech diagnostycznych dodatkowo utrudniają prawidłowe oznaczanie okazów. Problem ten może być szczególnie istotny w przypadku materiału zielnikowego, ponieważ proces suszenia, prasowania i długotrwałego przechowywania może wpływać na stan zachowania niektórych cech morfologicznych

(Espinosa et al., 2018; Heberling, 2022). Dodatkową trudność mogą stanowić również osobniki znajdujące się na różnych etapach rozwoju oraz liście powstające w różnych częściach sezonu wegetacyjnego. Wykazano bowiem, że u *Alchemilla* niektóre cechy, takie jak zagęszczenie owłosienia ogonków liściowych, mogą różnić się pomiędzy młodymi
i starszymi osobnikami oraz liśćmi rozwijanymi we wcześniejszej i późniejszej części sezonu (Faghir et al., 2014b). Ograniczenia te uzasadniają potrzebę uzupełnienia klasycznego podejścia morfologicznego o ilościowe i powtarzalne metody oceny wybranych cech, przy zachowaniu znaczenia pełnej analizy diagnostycznej okazu.

W trudnych taksonomicznie grupach roślin zestawianie różnych źródeł danych pozwala ocenić, czy wskazują one podobne wzorce zróżnicowania gatunków. Tego rodzaju podejście było szeroko stosowane u rodzajów należących do rodziny Rosaceae. Obejmowało ono m.in. łączenie danych morfologicznych i morfometrycznych z molekularnymi, jak w przypadku rodzaju *Prunus* L. (Depypere et al., 2009). Wykorzystywano również połączenie danych morfologicznych i molekularnych u rodzaju *Rubus* L. (Huang et al., 2023), a także szerszy zestaw danych morfometrycznych, molekularnych oraz ekologicznych u rodzaju *Rosa* L. (Yuan et al., 2025). Również w obrębie rodzaju *Alchemilla* wykorzystywano różne źródła informacji taksonomicznej, obejmujące cechy morfologiczne i morfometryczne, mikromorfologiczne, dane kariologiczne oraz markery molekularne (Sepp & Paal, 1998; Hayırlıoğlu-Ayaz & İnceer, 2006; Gehrke et al., 2008; Faghir et al., 2014a, 2014b; Morales-Briones et al., 2022; Nyambayar et al., 2025). Badania te wskazują, że zestawienie różnych typów danych może mieć istotny potencjał w identyfikacji taksonomicznej oraz delimitacji taksonów. W niniejszej rozprawie zastosowano trzy główne grupy metod: morfometryczne, mikromorfologiczne oraz molekularne, których możliwości i znaczenie w badaniach taksonomicznych omówiono poniżej.

Morfometria jest ilościowym podejściem wykorzystywanym do opisu i analizy kształtu oraz wielkości struktur biologicznych (Cope et al., 2012). Jest szeroko stosowana w taksonomii, systematyce, biologii rozwoju, morfologii oraz hodowli roślin. W badaniach botanicznych metody morfometryczne mogą być wykorzystywane do analizy różnorodnych struktur, w tym liści, kwiatów, owoców, a nawet całych roślin. Ich zastosowanie w taksonomii znacznie wzrosło wraz z postępującą digitalizacją

kolekcji botanicznych, która ułatwia prowadzenie analiz opartych na obrazach cyfrowych.

Analizy morfometryczne mogą wspierać identyfikację gatunków, w tym ocenę granic zasięgów geograficznych (Wilkin, 1999; Du et al., 2006; Gage & Wilkin, 2008), badania zmienności rozwojowej w obrębie gatunków (Chitwood et al., 2016), a także analizę wpływu czynników środowiskowych i klimatycznych na morfologię roślin, w szczególności na kształt i wielkość liści (Royer, 2005; Cope et al., 2012; Klein & Svoboda, 2017).

Zarówno organy generatywne, takie jak owoce, jak i organy wegetatywne, takie jak liście, są szczególnie dobrze przystosowane do analiz morfometrycznych, ponieważ ich kształt można stosunkowo łatwo zdigitalizować i porównywać w obrębie dużej liczby okazów. Istotnym źródłem materiału do takich badań są kolekcje zielnikowe, zapewniające dostęp do okazów zebranych na rozległych obszarach geograficznych i w długich przedziałach czasowych. Postępująca digitalizacja tych zbiorów dodatkowo zwiększa ich potencjał badawczy, umożliwiając analizę dużej liczby okazów bez konieczności bezpośredniego dostępu do materiału źródłowego. W porównaniu z tradycyjnymi podejściami opartymi głównie na pomiarach wykonywanych ręcznie, morfometria cyfrowa pozwala na bardziej efektywną, ilościową i powtarzalną ocenę zmienności morfologicznej.

Dostępne cyfrowe obrazy okazów zielnikowych *Alchemilla* umożliwiają zebranie materiału do ilościowych badań kształtu liści. Materiał ten wymaga jednak starannej selekcji przed włączeniem do analiz. Kształt liścia jest wykorzystywany przy identyfikacji przedstawicieli rodzaju i był przedmiotem wcześniejszych analiz morfometrycznych (Sepp & Paal, 1998; Pihu et al., 2009; Zhukova, 2020). Badania Sepp i Paal wykazały, że wiele mikrogatunków tworzy morfologiczne kontinuum, natomiast Pihu et al. analizowali stabilność cech oraz możliwość ich wykorzystania do rozróżniania gatunków. Z kolei Zhukova (2020) uzyskał dla wybranych grup około 80% poprawnych klasyfikacji, przy czym obszary zmienności odpowiadające poszczególnym mikrogatunkom nadal częściowo się nakładały. Wykazano również, że u niektórych gatunków czynniki środowiskowe mogą wpływać na wielkość i kształt liści. Wyniki te wskazują, że kształt liścia może stanowić istotną, choć nie zawsze jednoznaczną, cechę diagnostyczną.

O ile użyteczność cech liści w taksonomii rodzaju *Alchemilla* była już przedmiotem wcześniejszych badań, znaczenie taksonomiczne kształtu niełupek nie zostało dotychczas ocenione ilościowo w obrębie rodzaju. Tym samym potencjalna przydatność cech morfometrycznych niełupek w identyfikacji i różnicowaniu gatunków pozostaje nadal słabo poznana.

Ocena kształtu i wymiarów organów stanowi jednak tylko jeden z poziomów analizy ich zróżnicowania. Dodatkowych informacji taksonomicznych mogą dostarczać również cechy mikromorfologiczne, obejmujące drobne struktury powierzchniowe niewidoczne lub słabo widoczne w analizach makromorfologicznych. Do ich szczegółowej oceny szeroko wykorzystuje się skaningową mikroskopię elektronową (SEM). SEM umożliwia szczegółową analizę powierzchni epidermy oraz innych drobnych struktur, które mogą nie być wystarczająco dobrze widoczne w obserwacjach makromorfologicznych lub przy użyciu mikroskopii świetlnej (Heywood, 1969; Fischer et al., 2024). Sama metoda niesie ze sobą wiele zalet, a jedną z najważniejszych jest możliwość uzupełnienia tradycyjnych opisów taksonomicznych o szczegółowe cechy powierzchniowe (Heywood, 1969). Niektóre cechy powierzchniowe mogą być stosunkowo stabilne i przydatne w systematyce roślin, jednak ich wartość należy oceniać osobno w badanej grupie (Barthlott, 1981). Pomimo możliwości uzyskiwania bardzo szczegółowych obrazów powierzchni należy jednak uwzględniać ryzyko występowania artefaktów obecnych na badanym materiale lub powstających podczas suszenia i przygotowania próbek (Pathan et al., 2008). Z wykorzystaniem SEM analizowane są m.in. morfologia i rozmieszczenie włosków (Faghir et al., 2010; Heo et al., 2013), budowa komórek epidermy (Oak et al., 2018; Song et al., 2024), cechy aparatów szparkowych (Li, 1989; Oak et al., 2018) oraz występowanie i struktura wosków epikutykularnych (Heo et al., 2013; Faghir et al., 2014a). Cechy te mogą różnić się pomiędzy spokrewnionymi taksonami i stanowić uzupełniające źródło informacji w ich charakterystyce taksonomicznej.

W obrębie rodzaju *Alchemilla* badania dotyczące mikromorfologii zarówno organów generatywnych, jak i wegetatywnych pozostają stosunkowo nieliczne. Dotychczas jedyne badanie poświęcone mikromorfologii niełupek koncentrowało się na gatunkach występujących w Iranie (Shokatyari et al., 2022). Wykazano w nim, że kilka cech mikromorfologicznych, w szczególności związanych z ornamentacją powierzchni oraz morfologią komórek epidermy, może stanowić użyteczne

uzupełniające źródło informacji przy identyfikacji gatunków, zwłaszcza gdy cechy te są interpretowane łącznie z innymi cechami morfologicznymi. Wskazuje to na istniejącą lukę badawczą oraz możliwość rozszerzenia wiedzy dotyczącej znaczenia taksonomicznego cech mikromorfologicznych niełupek w obrębie rodzaju.

Dostępne opracowania dotyczące mikromorfologii liści koncentrowały się natomiast na budowie epidermy oraz rozmieszczeniu włosków na blaszkach i ogonkach liściowych, głównie u gatunków występujących w Iranie (Faghir et al., 2014a, 2016). Badania te wykazały międzygatunkowe zróżnicowanie cech epidermy i owłosienia oraz wskazały, że część z nich może mieć znaczenie taksonomiczne. Nadal jednak niewiele wiadomo o stabilności tych cech w obrębie gatunków oraz o ich zgodności ze wzorcami zróżnicowania obserwowanymi na poziomie molekularnym. Badanie liści i niełupek pozwoliło ocenić zmienność fenotypową dwóch różnych organów. W odrębnej analizie zestawiono wybrane cechy powierzchni liści z wynikami badań molekularnych i cytometrycznych, aby sprawdzić, czy wskazują podobne wzorce zróżnicowania badanych taksonów.

Dane molekularne stanowią komplementarne źródło informacji taksonomicznej, umożliwiając ocenę zróżnicowania badanych taksonów na poziomie sekwencji DNA (Dayrat, 2005; Schlick-Steiner et al., 2010). Ich wykorzystanie pozwala porównać wzorce obserwowane na poziomie fenotypowym z różnicami genetycznymi oraz lepiej poznać relacje pomiędzy blisko spokrewnionymi taksonami (Duminil & Di Michele, 2009).

W przypadku rodzaju *Alchemilla* zastosowanie danych molekularnych dostarczyło istotnych informacji na temat historii ewolucyjnej oraz pozwoliło na wyróżnienie głównych linii ewolucyjnych, jednak rozdzielczość analiz w odniesieniu do niektórych blisko spokrewnionych taksonów pozostaje ograniczona (Gehrke et al., 2008; Gehrke et al., 2016). Jądrowy region ITS zazwyczaj wykazuje większą zmienność sekwencji niż wiele regionów plastydowych, co może zwiększać jego przydatność w analizach prowadzonych na niższych poziomach taksonomicznych. Jednak w apomiktycznych i poliploidalnych kompleksach roślinnych hybrydyzacja, ewolucja siatkowata, niepełne sortowanie linii rodowych oraz złożona ewolucja wielokopijnego nrDNA mogą zaburzać zgodność pomiędzy drzewami a granicami gatunkowymi (Fehrer et al., 2009; Hörandl et al., 2009; Wang et al., 2016;

Macháčková et al., 2022). Z tego względu zestawienie danych pochodzących z regionów jądrowych i plastydowych może dostarczać komplementarnych informacji o zróżnicowaniu i relacjach pomiędzy taksonami. W obrębie Rosaceae w analizach filogenetycznych stosowano wielolokusowe zestawy obejmujące region ITS wraz z markerami plastydowymi, w tym *matK*, *trnH-psbA* i *rpoC1* (Shi et al., 2013), natomiast markery *matK*, *trnH-psbA* i *rpoC1* wykorzystywano również w szerszych analizach filogenetycznych podrodziny Rosoideae (Chen et al., 2020). Pomimo stosowania wymienionych markerów DNA u spokrewnionego rodzaju Prunus (Shi et al., 2013) oraz innych przedstawicieli podrodziny Rosoideae (Chen et al., 2020), dotychczasowe badania dotyczące rodzaju *Alchemilla* obejmowały zestawy markerów ITS + *trnL-F* (Gehrke et al., 2008) oraz ITS + *trnL-F* + *matK* (Nyambayar et al., 2025). W przywołanych badaniach rodzaju *Alchemilla* nie zastosowano łącznie ITS oraz trzech regionów plastydowych analizowanych w niniejszej rozprawie (*matK*, *trnH-psbA* i *rpoC1*).

Powszechne ograniczenia związane z interpretacją markerów sekwencyjnych wskazują na potrzebę uzupełniania analiz molekularnych także o inne źródła informacji dotyczące organizacji i zróżnicowania genomu (Dayrat, 2005; Schlick-Steiner et al., 2010). Jednym z takich podejść jest zastosowanie cytometrii przepływowej (FCM), umożliwiającej ocenę zawartości DNA jądrowego oraz, przy odpowiednich danych porównawczych, pośrednie wnioskowanie o poziomie ploidalności (Doležel et al., 2007; Krahulcová & Rotreklová, 2010; Sliwinska et al., 2022). Metoda ta pozwala m.in. na określenie wielkości genomu, która może dostarczać dodatkowych informacji przy charakterystyce i różnicowaniu taksonów. W grupach roślin charakteryzujących się poliploidią analiza zawartości DNA może być szczególnie użyteczna jako uzupełnienie innych danych taksonomicznych. Cytometria przepływowa może być również łączona z markerami molekularnymi, co pozwala jednocześnie oceniać zróżnicowanie wielkości genomu oraz zróżnicowanie genetyczne badanych taksonów (Jędrzejczyk & Rewers, 2018).

Zastosowanie markerów sekwencyjnych oraz cytometrii przepływowej pozwala więc na ocenę zróżnicowania badanych taksonów na różnych poziomach organizacji genomu. Dane te stanowią komplementarne źródło informacji wobec cech morfologicznych, morfometrycznych i mikromorfologicznych. Nadal jednak

niewystarczająco poznane pozostaje, w jakim stopniu poszczególne grupy cech wskazują zgodne wzorce zróżnicowania pomiędzy gatunkami rodzaju *Alchemilla*.

W niniejszej rozprawie oceniono, w jakim stopniu badane cechy odpowiadają istniejącym oznaczeniom gatunkowym oraz mogą wspomagać różnicowanie wybranych taksonów *Alchemilla*. Interpretując uzyskane wyniki, uwzględniono różnice w doborze analizowanych okazów i gatunków.

4. Cele badawcze

Głównym celem prowadzonych badań było określenie zróżnicowania morfometrycznego, mikromorfologicznego oraz molekularnego wybranych gatunków rodzaju *Alchemilla* L. (Rosaceae) oraz ocena, w jakim stopniu badane cechy odpowiadają oznaczeniom gatunkowym analizowanego materiału i mogą wspomagać różnicowanie taksonów.

Szczegółowym celem badawczym było opisanie zmienności cech powierzchni liści i niełupek wybranych przedstawicieli rodzaju *Alchemilla* L. oraz ocena ich potencjalnej przydatności w różnicowaniu badanego materiału.

Kolejnym celem szczegółowym było określenie zmienności kształtu liści i niełupek oraz ocena, w jakim stopniu uzyskane wyniki odpowiadają oznaczeniom gatunkowym analizowanych okazów. W badaniu niełupek sprawdzono również ich związek z wybranymi zmiennymi klimatycznymi i glebowymi.

Dodatkowym celem było określenie zróżnicowania molekularnego oraz ocena zdolności wybranych markerów DNA do różnicowania badanych taksonów. Oszacowano także zawartość jądrowego DNA i oceniono, czy jej wartości wykazują zróżnicowanie odpowiadające oznaczeniom gatunkowym badanych próbek.

Na podstawie niniejszych celów sformułowano następujące hipotezy badawcze:

1. Kształt liści i niełupek różni się między badanymi gatunkami rodzaju *Alchemilla* L.
2. Cechy mikromorfologiczne liści i niełupek wykazują zróżnicowanie między badanymi gatunkami *Alchemilla* L.
3. Zróżnicowanie sekwencji regionu ITS i badanych regionów plastydowych odpowiada oznaczeniom gatunkowym analizowanych okazów *Alchemilla* L.
4. Zawartość jądrowego DNA różni się między badanymi gatunkami rodzaju *Alchemilla* L.

5. Prace wchodzące w skład rozprawy doktorskiej

Praca nr 1: Kosiróg-Ceynowa A. M., Jaskólska J., Rewicz A., Szlachetko D. L., Nowak S. **Limited taxonomic value of achene shape but diagnostic potential of achene micromorphology in selected *Alchemilla* L. (Rosaceae) taxa from Poland.** *Acta Societatis Botanicorum Poloniae* (po 1. rundzie recenzji).

W manuskrypcie skoncentrowano się na znaczeniu analiz morfometrycznych oraz mikromorfologicznych organów generatywnych, jakimi są owoce, jako dodatkowego źródła informacji taksonomicznej w obrębie rodzaju *Alchemilla* L.

Cechy owoców nie stanowią podstawowego kryterium identyfikacyjnego i nie są głównymi cechami branymi pod uwagę podczas oznaczania okazów do gatunku. Jednak analiza ich kształtu oraz powierzchni może dostarczać informacji uzupełniających w różnicowaniu blisko spokrewnionych taksonów w obrębie rodzaju *Alchemilla*. Należy zaznaczyć, że mikromorfologia owoców typu niełupka była w tym rodzaju badana dotychczas w ograniczonym zakresie. Dlatego przeprowadzone analizy oraz połączenie dwóch podejść stanowiły uzupełnienie wcześniejszych obserwacji i pozwoliły ocenić, czy badane cechy różnią się między analizowanymi gatunkami. Co istotne, przeanalizowano również możliwy związek obserwowanego zróżnicowania z warunkami środowiskowymi.

Cechy mikromorfologiczne wykazały większy potencjał diagnostyczny, szczególnie w odniesieniu do ornamentacji powierzchni, morfologii komórek epidermy oraz wybranych cech ścian komórkowych. Natomiast analizy morfometryczne kształtu niełupek wykazały znaczne nakładanie się zakresów zmienności pomiędzy badanymi gatunkami i nie pozwoliły na wyraźne rozdzielenie taksonów, co wskazuje na ograniczoną wartość samego kształtu owocu jako niezależnego kryterium identyfikacyjnego.

Zestawienie danych morfometrycznych i mikromorfologicznych wykazało, że w analizowanym materiale cechy mikromorfologiczne niełupek były silniej związane z oznaczeniami gatunkowymi niż ilościowe cechy ich kształtu. Interpretacja tego wyniku wymaga jednak uwzględnienia różnic w zróżnicowaniu wewnątrzgatunkowym cech mikromorfologicznych. Analizy środowiskowe nie dostarczyły jednoznacznych dowodów na związek kształtu niełupek z badanymi zmiennymi klimatycznymi oraz glebowymi.

Praca nr 2: Kosiróg-Ceynowa A. M., Dudek M., Jędrzejczyk I., Jaskólska J., Łuszczek D., Narajczyk M., Szlachetko D. L., Nowak S. **Leaf character variation does not consistently track molecular differentiation in selected *Alchemilla* L. species.** *International Journal of Molecular Sciences* (złożona w czasopiśmie).

W niniejszym badaniu zastosowano integracyjne podejście obejmujące skaningową mikroskopię elektronową (SEM) powierzchni blaszki liściowej, analizy sekwencji jądrowego regionu ITS i trzech regionów plastydowych (*matK*, *rpoC1* i *trnH-psbA*) oraz cytometryczną ocenę zawartości jądrowego DNA u wybranych europejskich gatunków *Alchemilla*. Analizy powierzchni blaszki liściowej wykazały zróżnicowanie, szczególnie pod względem wielkości ząbka szczytowego. Dodatkowo stwierdzono zróżnicowanie mikromorfologiczne pod względem gęstości owłosienia, rozmieszczenia oraz morfologii trichomów występujących na blaszce liściowej. Na podstawie względnej wielkości ząbka szczytowego i zagęszczenia owłosienia wyróżniono trzy kombinacje cech liścia. Żadna z wyróżnionych kombinacji nie była jednak ograniczona do jednego morfologicznie zidentyfikowanego gatunku.

Spośród analizowanych markerów molekularnych ITS wykazywał najwyższy udział miejsc zmiennych i parsymonicznie informatywnych. Co więcej, marker jądrowy pozwolił na odtworzenie szerszej struktury filogenetycznej. Jednak ani analizy filogenetyczne, ani sieciowe nie umożliwiły konsekwentnego wyróżnienia poszczególnych gatunków wśród badanych europejskich taksonów. Markery plastydowe również wykazały ograniczoną zdolność różnicowania badanych taksonów i w analizowanych zbiorach sekwencji niższą rozdzielczość niż marker jądrowy ITS. Dodatkowo zawartość jądrowego DNA mieściła się w wąskim zakresie i w znacznym stopniu nakładała się pomiędzy taksonami. Badania molekularne nie dostarczyły więc jednoznacznych odpowiedzi dotyczących granic pomiędzy badanymi gatunkami, ale wskazały kierunki dalszych analiz.

Ogólnie żadna z zastosowanych metod, rozpatrywana niezależnie, nie wykazała stałej i jednoznacznej zgodności z identyfikacją gatunków opartą na cechach morfologicznych. Wyniki wskazują, że mikromorfologia liści, markery molekularne oraz oszacowania zawartości jądrowego DNA dostarczają uzupełniających informacji, lecz w badanym materiale żadne z tych danych nie stanowiło samodzielnej podstawy do identyfikacji gatunków.

Praca nr 3: Kosiróg-Ceynowa A. M., Nowak S., Jaskólska J., Szlachetko D. L. **Can leaf morphometry support species identification in *Alchemilla*? Evidence from digitised European herbarium specimens.** *PhytoKeys* (złożona w czasopiśmie).

W pracy głównym celem była ocena przydatności morfometrii liści jako narzędzia wspomagającego identyfikację taksonomiczną przedstawicieli rodzaju *Alchemilla* L. Inspiracją do podjęcia tych badań były obserwacje zmienności cech liści poczynione podczas przygotowywania pracy mikromorfologicznej oraz potrzeba odrębnej, ilościowej oceny kształtu blaszki liściowej. Dodatkowym impulsem była duża dostępność materiału zielnikowego w obrębie badanego rodzaju, co stworzyło możliwość wykorzystania zdigitalizowanych okazów w ilościowych analizach morfometrycznych.

Rodzaj *Alchemilla*, ze względu na duże podobieństwo morfologiczne pomiędzy taksonami, stanowi wyzwanie identyfikacyjne nawet dla wykwalifikowanego taksonoma. Dlatego podjęto próbę określenia, czy ilościowa analiza kształtu liścia wykazuje zgodność z oznaczeniami okazów zielnikowych oraz pozwala różnicować blisko spokrewnione taksony. Dodatkowym celem było sprawdzenie, czy okazy oznaczone jedynie jako *Alchemilla* sp. mogą zostać przyporządkowane do konkretnego gatunku na podstawie cech morfometrycznych liścia.

W badaniu przeanalizowano 742 liście reprezentujące 514 okazów zielnikowych, w tym 491 okazów przypisanych na etykietach do 12 gatunków rodzaju *Alchemilla* oraz 23 okazy oznaczone jedynie jako *Alchemilla* sp. Kształt blaszki liściowej oceniano z wykorzystaniem eliptycznych deskryptorów Fouriera (EFD) oraz wybranych parametrów morfometrycznych w tym współczynników kształtu. Do oceny zróżnicowania zastosowano m.in. PCA, PERMANOVA, NMDS oraz hierarchiczną analizę skupień.

Uzyskane wyniki wykazały znaczne nakładanie się zakresów zmienności pomiędzy badanymi taksonami. Analiza PCA nie pozwoliła na wyraźne rozdzielenie taksonów. PERMANOVA wykazała różnice między siedmioma odpowiednio reprezentowanymi gatunkami, jednak przynależność gatunkowa wyjaśniała tylko 6,7% zmienności. NMDS potwierdziło znaczne nakładanie się okazów, natomiast analiza hierarchiczna wyodrębniła dwa klastry fenotypowe, które nie odpowiadały oznaczeniom gatunkowym.

Zastosowane analizy nie pozwoliły również na jednoznaczne przyporządkowanie okazów *Alchemilla* sp. do konkretnych gatunków. Wyniki wskazują więc, że morfometria liści może stanowić wartościowe narzędzie wspomagające ocenę zmienności i porównywanie okazów, jednak nie powinna być traktowana jako samodzielna metoda identyfikacji gatunków rodzaju *Alchemilla*.

6. Podsumowanie

W przedstawionej rozprawie oceniono przydatność cech morfometrycznych i mikromorfologicznych, wybranych markerów DNA oraz zawartości jądrowego DNA do różnicowania wybranych gatunków rodzaju *Alchemilla*. Badania zebrane w trzech pracach obejmowały częściowo różne zestawy gatunków i okazów, co ogranicza zakres bezpośrednich porównań między typami danych. Analizy morfometryczne liści i niełupek pozwoliły ilościowo scharakteryzować ich zmienność. W obu zbiorach stwierdzono jednak znaczne nakładanie się cech między badanymi gatunkami. Mimo wykrycia wybranych różnic między grupami sam kształt żadnego z tych organów nie stanowił wystarczającej podstawy do jednoznacznej identyfikacji gatunków. Wybrane cechy powierzchni niełupek wykazały większy potencjał różnicujący niż ich kształt, szczególnie w odniesieniu do ornamentacji oraz morfologii komórek epidermy. Ich przydatność do identyfikacji wymaga jednak dalszej oceny zmienności w obrębie gatunków. Cechy powierzchni liści, w tym względna wielkość ząbka szczytowego oraz zagęszczenie i rozmieszczenie trichomów, również wykazywały zmienność, lecz wyróżnione kombinacje cech nie były swoiste dla poszczególnych gatunków.

Region ITS wykazał największy udział miejsc zmiennych i informatywnych parsymonicznie spośród badanych markerów oraz pozwolił rozpoznać szerszą strukturę filogenetyczną. Nie umożliwił jednak konsekwentnego rozróżnienia badanych gatunków europejskich; w analizie sieciowej część sekwencji przypisanych do różnych gatunków dzieliła te same haplotypy. Badane regiony plastydowe również miały ograniczoną rozdzielczość. Uzyskane wzorce molekularne nie odpowiadały konsekwentnie oznaczeniom gatunkowym ani wyróżnionym kombinacjom cech powierzchni liści.

Zawartość jądrowego DNA wykazywała niewielkie zróżnicowanie i znaczne nakładanie się wartości między badanymi gatunkami. Dane te nie pozwalają samodzielnie ustalić poziomów ploidalności ani wyjaśnić przyczyn obserwowanej zmienności; potrzebne byłyby w szczególności liczby chromosomów i liczniejsze próbkowanie. Badane źródła danych różniły się przydatnością w ocenie zróżnicowania *Alchemilla*, lecz żadne nie zapewniło konsekwentnej identyfikacji wszystkich analizowanych gatunków. Największy potencjał różnicujący wykazały wybrane cechy powierzchni niełupek. Pozostałe analizy dostarczyły przede wszystkim informacji

o zmienności i ograniczeniach samodzielnego stosowania poszczególnych cech oraz markerów.

7. Wnioski

Przeprowadzone badania z użyciem metod morfometrycznych, mikromorfologicznych oraz molekularnych wykazały, że:

1. Cechy morfometryczne owoców mają ograniczoną wartość przy oznaczaniu okazów do gatunków rodzaju *Alchemilla*. Obserwowane zróżnicowanie kształtu nie pozwalało na jednoznaczne rozdzielenie analizowanych taksonów, a zakresy zmienności poszczególnych gatunków w znacznym stopniu się nakładały. Nie wykazano również istotnego związku kształtu niełupek z analizowanym łącznie zestawem zmiennych klimatycznych i glebowych.
2. Analizy morfometryczne blaszki liściowej wykazały zróżnicowanie pomiędzy badanymi taksonami, jednak zakresy zmienności w znacznym stopniu się nakładały. Cechy kształtu blaszki liściowej pozwalają ilościowo opisać zmienność, lecz ich samodzielna wartość w identyfikacji gatunków była w badanym materiale ograniczona.
3. Cechy mikromorfologiczne niełupek wykazały większy potencjał diagnostyczny niż ich cechy morfometryczne. Szczególne znaczenie miały ornamentacja powierzchni oraz cechy komórek epidermy. Cechy te powinny być jednak interpretowane łącznie z innymi źródłami informacji taksonomicznej.
4. Analizy makro- i mikromorfologiczne liści wykazały zróżnicowanie badanego materiału. Najwyraźniejsza zmienność dotyczyła względnej wielkości ząbka szczytowego oraz zagęszczenia i rozmieszczenia trichomów na powierzchni blaszki liściowej. Żaden z obserwowanych zestawów cech nie był jednak wystarczający do jednoznacznej identyfikacji okazów na poziomie gatunku.
5. Spośród badanych markerów molekularnych największy udział miejsc zmiennych i informatywnych parsymonicznie wykazał jądrowy region ITS, natomiast markery plastydowe *matK*, *trnH-psbA* i *rpoC1* charakteryzowały się ograniczoną rozdzielczością w analizowanych zbiorach sekwencji. Żaden z zastosowanych markerów nie umożliwił jednak jednoznacznego rozróżnienia blisko spokrewnionych gatunków *Alchemilla*.
6. Analiza cytometryczna wykazała niewielkie zróżnicowanie zawartości jądrowego DNA oraz znaczne nakładanie się uzyskanych wartości pomiędzy badanymi taksonami. Pomimo występowania pojedynczych istotnych różnic zakresy wartości nie odpowiadały jednoznacznie granicom morfologicznie

wyróżnianych gatunków, dlatego zawartość jądrowego DNA nie może stanowić samodzielnego kryterium diagnostycznego w badanym materiale.

7. Badane cechy morfometryczne i mikromorfologiczne, markery DNA oraz zawartość jądrowego DNA dostarczyły informacji o zróżnicowaniu badanych taksonów rodzaju *Alchemilla*, lecz w różnym stopniu odpowiadały oznaczeniom gatunkowym analizowanego materiału. Ich zestawienie pozwoliło ocenić przydatność i ograniczenia poszczególnych źródeł danych, nie zapewniając jednoznacznej identyfikacji wszystkich badanych gatunków.

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9. Praca nr 1:

Original research paper

Limited taxonomic value of achene shape but diagnostic potential of achene micromorphology in selected *Alchemilla* L. (Rosaceae) taxa from Poland

Abstract

Species delimitation in taxonomically complex plant groups remains challenging because morphologically similar taxa often exhibit only subtle phenotypic differences. *Alchemilla* L. (Rosaceae) is a classic example of such a genus, characterized by numerous microspecies, widespread apomixis and unresolved evolutionary relationships. We performed the first quantitative assessment of the taxonomic significance of achene macro- and micromorphology in Central European representatives of *Alchemilla*. Achene shape was analyzed using Elliptical Fourier Descriptors and complementary morphometric indices, whereas surface characters were examined using scanning electron microscopy. Multivariate analyses revealed that achene macromorphology possesses limited discriminatory power, with most morphological variation occurring within rather than among species. Hierarchical clustering failed to recover species-specific groups and different phenotypic clusters frequently occurred within the same population and even within individual specimens. In contrast, micromorphological characters, particularly surface ornamentation and epidermal cell morphology, provided greater taxonomic resolution, with *A. subglobosa* representing the most distinctive species. Together with previous evidence from Iranian taxa, our results indicate that low interspecific differentiation in achene morphology is likely a general feature of *Alchemilla*. We conclude that achene micromorphology

represents a valuable supplementary source of taxonomic evidence, whereas achene shape alone is of limited systematic significance within the genus.

Keywords: *Alchemilla*; Scanning Electron Microscope (SEM); achene morphometrics; micromorphology; shape features; taxonomy.

Running head: Taxonomic value of *Alchemilla* achenes

Introduction

The genus *Alchemilla* L. was first described by Linnaeus in 1753 and belongs to the family Rosaceae Juss. It is one of the largest genera within the family, comprising approximately 1000 species, many of which are apomictic microspecies. About 300 species have been described in Europe, most of which are microspecies of *Alchemilla vulgaris* L. (Fröhner, 1986; Gehrke et al., 2008). In Poland, approximately 60 taxa have been recorded (Mirek et al., 2020). Representatives of the genus occur predominantly in Eurasia, with additional native representatives in East Africa and alien populations established in North America and Australia. In Europe, the main centers of occurrence are likely to be mountain ranges such as the Alps, the Caucasus and the Carpathian Mountains (Pihu et al., 2009; Sepp & Paal, 1998).

The genus *Alchemilla*, despite its remarkable species richness, presents considerable taxonomic challenges. Many species form complexes of morphologically very similar taxa, making their identification and the delimitation of clear species boundaries difficult. A major factor contributing to this complexity is the widespread occurrence of apomixis (Pihu et al., 2009; Sepp & Paal, 1998; Sepp & Paal, 2000), resulting in increased genetic polymorphism (Sepp et al., 2000). Genetic diversity within the

genus represents an equally significant challenge. A well-resolved phylogeny of *Alchemilla* is still lacking and many clades remain unresolved, forming polytomies (Feng et al., 2017; Gehrke et al., 2008). Moreover, multiple ancient polyploidization events have been inferred during the evolutionary history of the genus (Morales-Briones et al., 2022), while reticulate evolution, hybridization and polyploidy have been demonstrated in the closely related genus *Lachemilla* Rydb. (Morales-Briones et al., 2018a, 2018b). Consequently, there is a continuing need to identify additional sources of taxonomic evidence that may improve species delimitation within this morphologically complex genus. In such a system, evaluating the stability and diagnostic value of morphological characters is particularly important, because potentially useful taxonomic traits must remain informative despite substantial morphological similarity among closely related taxa.

The exploration of new sources of taxonomic evidence to improve the understanding of taxonomically complex groups has become a common direction in systematic research. Seeds and fruits, including both their morphology and surface micromorphology, represent one such valuable source of taxonomic information. This is particularly important in the case of small fruits, such as achenes and nutlets, where these characters can be easily overlooked. Such analyses have been carried out extensively in representatives of Asteraceae (Chehregani & Mahanfar, 2007; Ghimire et al., 2016; Karaismailoğlu et al., 2024; Rewicz et al., 2020; Zareh, 2024) and have also been reported for members of Rosaceae (Jagodziński et al., 2016; Sadeghi et al., 2021), Polygonaceae (Kong et al., 2018; Sumbembayev et al., 2023) and Lamiaceae (Gutiérrez del Pozo et al., 2025; Jabeen et al., 2025). These studies confirm that analyses of both fruit shape and surface micromorphology have considerable potential for taxonomic identification and the delimitation of taxa.

However, the diagnostic value of such characters is group-dependent and requires evaluation of both inter- and intraspecific variation.

Despite the increasing application of seed and fruit morphology in plant systematics, achene characters remain poorly investigated in *Alchemilla*. To date, the only study conducted on *Alchemilla* has focused on the achene micromorphology of species occurring in Iran (Shokatyari et al., 2022). That study demonstrated that several micromorphological characters, particularly those related to surface ornamentation and epidermal cell morphology, may provide useful supplementary evidence for species identification when interpreted together with other morphological traits. At the same time, considerable similarity was observed among several of the examined taxa, and the micromorphological patterns showed limited correspondence with the existing classification. However, the taxonomic significance of achene shape has never been quantitatively evaluated within the genus and the usefulness of these characters outside the Iranian flora remains unknown. It therefore remains unclear whether the relatively limited differentiation observed among Iranian taxa also characterizes geographically and taxonomically distinct representatives of the genus.

Given this evident knowledge gap, the present study represents the first comprehensive investigation of achene macro- and micromorphology in Polish representatives of *Alchemilla*. We evaluated the taxonomic significance of both quantitative achene morphometry and SEM-based micromorphological characters in selected species representing populations from lowland and mountainous regions.

Specifically, we aimed to (i) quantify variation in achene shape using conventional morphometric descriptors and Elliptical Fourier Descriptors (EFDs), (ii) characterize achene micromorphology using scanning electron microscopy (SEM), (iii) assess whether the integration of macro- and micromorphological characters improves

differentiation among the examined taxa, and (iv) explore whether variation in achene morphology is associated with environmental gradients. We hypothesized that achene macromorphology would show substantial overlap among species, whereas micromorphological characters, particularly surface ornamentation and epidermal cell features, would provide greater taxonomic resolution.

Material and methods

Material

The study material comprised achenes representing 17 species of the genus *Alchemilla* L., collected from 68 localities in lowland and mountainous regions of Central Europe: *A. acutiloba* Opiz, *A. crinita* Buser, *A. glabra* Neygenf., *A. glabricaulis* H.Lindb., *A. gracilis* Walters, *A. glaucescens* Wallr., *A. gorcensis* Pawł., *A. hirsuticaulis* H.Lindb., *A. monticola* Opiz, *A. obtusa* Buser, *A. plicata* Buser, *A. propinqua* H.Lindb., *A. pseudoincisa* Pawł., *A. subcrenata* Buser, *A. subglobosa* C.G.Westerl., *A. walasii* Pawł., and *A. xanthochlora* Rothm. Species identification followed the taxonomic keys of Rutkowski (2006), Szafer et al. (1969), and Pawłowski (1956).

All achene material was obtained from 71 herbarium vouchers deposited in the collections of the University of Gdańsk (UGDA) and the University of Łódź (LOD) (Table S1). The morphometric dataset comprised 296 individual achenes obtained from 71 of these vouchers and represented all 17 species. Individual achenes originating from the same voucher were treated as subsamples rather than independent biological replicates. SEM observations were conducted on a subset of 13 species for which suitable material was available (Table 1). The SEM dataset did not include *A. glabricaulis*, *A. hirsuticaulis*, *A. obtusa*, or *A. pseudoincisa*, because the preservation of the available material did not allow SEM images of sufficient quality for reliable character assessment. Only fully developed, mature, and undamaged achenes were selected for morphometric and SEM analyses.

Methods

Achene macromorphology

Image acquisition and morphometric measurements

To quantify achene shape variation, contour analysis based on Elliptical Fourier Descriptors (EFDs) was employed, complemented by selected shape indices including aspect ratio, circularity, roundness and solidity.

Images of all 296 individual achenes were acquired using a Zeiss SteREO Discovery V12 microscope at 1.0× magnification and a fixed working distance of 81 mm and processed with ZEN 3.2 (blue edition). Achenes were photographed in a standardized orientation, with the same side facing the camera, the longitudinal axis consistently aligned, and the hilum directed toward the base of the image. Spatial scaling was assigned in ZEN using the "Assign Scaling to Image" function, and a 1-mm scale bar was embedded in the exported TIFF images. Additional image adjustments were performed using Adobe Photoshop, version 25.0 (Adobe, 2024). Individual achenes were manually separated from the original background and placed on a uniform white background to remove background and shadow artefacts. For contour analysis, the resulting achene silhouettes were converted to black binary objects. No resizing, geometric transformation, perspective correction, or intentional modification of the original achene shape was applied.

Conventional shape descriptors were calculated using ImageJ (Abràmoff et al., 2004) with macros developed according to the protocol of Klein and Svoboda (2017). Aspect ratio, circularity, roundness, and solidity were initially calculated.

Elliptical Fourier analysis

Contour analysis was performed using the SHAPE package following Iwata and Ukai (2002). Binary achene contours were converted to chain codes using ChainCoder and subsequently transformed into normalized Elliptical Fourier Descriptors using CHC2NEF. Twenty harmonics were calculated for each contour. EFD normalization was based on the longest radius, providing additional standardization of contour orientation. The coefficients of the first harmonic (a1, b1, c1, and d1) were held constant during normalization, whereas coefficients a2-d20, corresponding to 76 coefficients, were included in the subsequent analysis.

Principal component analysis of the EFD coefficients was performed using the PrinComp module of SHAPE based on the covariance matrix. SHAPE identified 11 effective principal components. The first five components were used to reconstruct mean achene contours and contour variation corresponding to ±2.5 standard deviations, whereas the first two EFD-derived principal component scores (EFD-PC1 and EFD-PC2) were retained as quantitative descriptors of achene outline for subsequent integrated multivariate analyses.

Statistical analysis of achene shape

Because multiple achenes were measured from individual herbarium vouchers, herbarium vouchers rather than individual achenes were treated as the independent sampling units in the principal multivariate analyses. For each voucher, mean values of the conventional shape descriptors and EFD-PC scores were calculated across the available achenes, resulting in 71 voucher-level observations. This approach was used to avoid pseudoreplication caused by treating multiple achenes originating from the same voucher as independent biological replicates.

Relationships among the conventional shape descriptors were initially examined using Pearson correlation coefficients. Roundness showed the expected strong negative association with aspect ratio ($r = -0.98$), reflecting the mathematical dependence between these two descriptors rather than independent biological information (Figure 1).

Roundness was therefore excluded from subsequent multivariate analyses to avoid redundant representation of the same component of achene shape. Consequently, aspect ratio, circularity, and solidity were retained as conventional shape descriptors. Principal component analysis (PCA) was performed on standardized voucher-level mean values of aspect ratio, circularity, solidity, EFD-PC1, and EFD-PC2. All variables were centered and scaled prior to analysis. PCA was used to summarize the major patterns of achene shape variation and to assess the degree of morphological overlap among species.

Statistical analyses and visualization were performed in R version 4.4.3 (R Core Team, 2024) using RStudio 2024.04.1 “Chocolate Cosmos” (Posit Team, 2024). The analyses used the following R packages: corrplot (v. 0.95), vegan (v. 2.7-5; Oksanen et al., 2026), ggplot2 (v. 4.0.3; Wickham, 2016), and ggrepel (v. 0.9.8).

Achene micromorphology

SEM analyses

The micromorphology of the achenes was investigated with a Phenom Pro X scanning electron microscope at the Department of Invertebrate Zoology and Hydrobiology, University of Lodz (Poland). Samples were sputter-coated with a 4 nm gold layer before imaging. Micromorphological observations were restricted to 13 species, as the

available material of *Alchemilla glabricaulis*, *A. hirsuticaulis*, *A. pseudoincisa*, and *A. obtusa* did not yield SEM micrographs of sufficient quality for reliable assessment of micromorphological characters. In particular, fine surface details were insufficiently resolved for consistent character scoring. Additional well-preserved herbarium material suitable for SEM examination was not available for these taxa.

For each herbarium voucher included in the SEM analysis, at least 10 mature and visually undamaged achenes were mounted on a single SEM stub. Prior to SEM examination, the available achenes were visually screened using a stereomicroscope to select suitable material. During SEM examination, all mounted achenes were inspected across different surface regions and at multiple magnifications, ranging approximately from ×200 to ×3300. The examination was qualitative rather than based on a predetermined number of micrographs, fixed surface areas, or fixed magnifications. Depending on the observed surface characteristics, multiple regions and magnifications were examined, and representative features were documented photographically. Several dozen to several hundred micrographs were typically obtained from each stub. Character states were assigned by an experienced researcher based on the overall examination of the achene surfaces rather than on individual micrographs or a fixed number of measurements.

SEM micrographs were subjected only to global adjustments of brightness, contrast, highlights, shadows, sharpness, and clarity in Canva. No local retouching or structural modification of the achene surface was performed. CorelDRAW 2018 was used solely to arrange the selected micrographs into figure plates.

Micromorphological characters

Qualitative micromorphological characters were assessed based on SEM images and stereomicroscope observations. The following traits were examined: achene surface ornamentation, epidermal cell shape, periclinal cell wall morphology, anticlinal cell wall morphology, epidermal cell wall type, achene apex type, achene shape and hilum position.

The terminology used to describe achene surface ornamentation follows Bojnanský and Fargašová (2007) and Barthlott (1981), with minor modifications adapted to the studied material.

Character states were assigned based on the overall appearance of the examined surface area and the dominant morphology of epidermal cells rather than on measurements of individual cells. The distinction between polygonal and polygonal-irregular epidermal cells was based on the degree of regularity of cell outlines: in the polygonal-irregular category, the predominantly polygonal organization was retained, but a greater proportion of cells showed irregular outlines and increased variation in cell shape and wall configuration.

Integrated macro- and micromorphological analysis

To assess whether the integration of quantitative achene-shape descriptors and qualitative micromorphological characters improved differentiation among the examined taxa, a combined multivariate analysis was performed using Gower dissimilarities. Gower distance was selected because the combined dataset contained both continuous and categorical variables (Table S3). The quantitative component comprised voucher-level mean values of aspect ratio, circularity, solidity, EFD-PC1, and EFD-PC2. The Gower distance matrix was calculated using the previously described shape features together with qualitative characteristics of the achene surface.

These included apex characteristics (acute-curved, acute, or blunt-acuminate), epidermal cell shape (polygonal, polygonal-irregular, or elongated polygonal-irregular), periclinal relief (raised or depressed), anticlinal relief (raised or depressed), anticlinal wall pattern (straight or undulate), sculpture (reticulate or colliculate), and surface type (types 1, 2, and 3). Binary variables were treated as asymmetric binary variables in the calculation of Gower dissimilarities, whereas variables with more than two character states were treated as nominal categorical variables. The integrated analysis was restricted to herbarium vouchers for which both quantitative achene-shape data and micromorphological character states were available. Principal Coordinates Analysis (PCoA) was performed on the resulting Gower dissimilarity matrix. A Lingoes correction was applied to account for negative eigenvalues. Associations of individual quantitative and micromorphological characters with the PCoA configuration were subsequently assessed using the envfit procedure with 9,999 permutations.

The association between species identity and the combined phenotypic dissimilarity matrix was tested using PERMANOVA with 9,999 permutations. To compare the relative contribution of the two components of the dataset, separate PERMANOVA analyses were additionally performed for the quantitative achene-shape variables and the micromorphological characters. Homogeneity of multivariate dispersion among species was assessed using PERMDISP. All multivariate analyses were performed in R version 4.4.3 (R Core Team, 2024), primarily using the vegan package (v. 2.7-5).

Environmental analysis of achene morphology

Environmental data and predictor selection

To explore whether variation in achene morphology was associated with environmental conditions, climatic and soil variables were extracted for the geographic coordinates

of the herbarium vouchers. Climatic data were obtained from WorldClim (Fick & Hijmans, 2017) with 2.5m resolution, whereas topsoil data were obtained from the Eurostat LUCAS Topsoil database (Ballabio et al., 2016; Ballabio et al., 2019). Environmental data were extracted in R using the terra package (v. 1.9-34).

The soil dataset included available water capacity (AWC), bulk density, calcium carbonate content ($CaCO_3$), cation exchange capacity (CEC), clay content, carbon-to-nitrogen ratio (C:N), coarse-fragment content, potassium (K), nitrogen (N), phosphorus (P), pH measured in $CaCl_2$, pH measured in H_2O, the $H_2O/CaCl_2$ pH ratio, sand content, and silt content. Climatic data comprised the 19 bioclimatic variables (BIO1-BIO19) obtained from the WorldClim database.

To reduce collinearity among environmental predictors, highly correlated variables were removed using an absolute Pearson correlation threshold of $|r| \geq 0.7$ (Figure 2). Following this procedure, BIO4, BIO15, and BIO12 were retained from the climatic dataset, and AWC, bulk density, C ratio, coarse fragment content, K, and pH from soil data.

Redundancy analysis

Associations between environmental variation and achene morphological variation were assessed using redundancy analysis (RDA). The response matrix consisted of five achene morphological variables: aspect ratio, circularity, solidity, PC1 EFDs, and PC2 EFDs (Table S3). Because raster data were unavailable for some samples, these samples were excluded from the analysis; ultimately, all 17 species and 68 records were included. Prior to RDA, environmental predictors and response variance were centered and standardized to unit variance using the scale = TRUE option. A full RDA model included three climatic predictors (BIO4, BIO12, and BIO15) and six soil predictors

(AWC, bulk density, C:N ratio, coarse-fragment content, K, and pH measured in H_2O). To assess the unique contributions of the two environmental predictor groups, partial RDAs were performed. Climatic variables were tested while conditioning on soil variables, and soil variables were tested while conditioning on climatic variables. Variance partitioning was used to separate the variation in achene morphology into fractions uniquely attributable to climate, uniquely attributable to soil, jointly explained by climate and soil, and unexplained variation. Multicollinearity among predictors in the full RDA model was assessed using variance inflation factors (VIF).

The significance of the overall RDA models was assessed using permutation tests with 9999 permutations. The effects of individual predictors were assessed using sequential (type I) and marginal permutation tests. Model fit was summarized using R^2 and adjusted R^2. The significance of the overall constrained models and individual environmental components was evaluated using permutation tests with 9999 permutations.

Results

Achene macromorphology

The morphometric dataset comprised 296 individual achenes representing 17 *Alchemilla* species and 71 herbarium vouchers (Table S1). The number of achenes examined per species ranged from 3 in *A. pseudoincisa* to 57 in *A. monticola*. Because multiple achenes originated from the same herbarium voucher, voucher-level means were used in the principal multivariate analyses. Representative achenes illustrating the macromorphological variation observed among the examined taxa are shown in Figure 3.

Elliptical Fourier analysis

The EFD-based PCA showed substantial overlap among the examined *Alchemilla* taxa, with no clear species-specific separation along the first two principal components (Figure 4A). PC1 explained 31.97% of the total contour variation and PC2 23.44%, together accounting for 55.41%. PC3, PC4, and PC5 explained 8.30%, 6.53%, and 4.81%, respectively, and the first five principal components accounted for 75.04% of the total contour variation (Table S2). Reconstructed contours along PC1-PC5 showed continuous variation in achene outline rather than discrete species-specific shape patterns (Figure 4B).

Statistical analysis of achene shape

To test whether achene shape has an impact on species discrimination, a PCA was conducted using scaled shape features: aspect ratio, circularity, solidity, and the first two principal components derived from EFDs (Figure 5). Roundness was excluded from the analysis because of its strong correlation with other shape variables. PC1 explained 35.69% of the variance, while PC2 explained 21.26%, accounting for 56.95% of the

total variance. The variables with the highest contributions to PC1 solidity (-0.651) and circularity (-0.596), whereas PC2 was primarily associated with aspect ratio (0.655) and the PC1 EFD component (-0.631). The second EFD component showed its strongest loading on PC3 (0.764). The samples were widely dispersed in the PCA space, with no clear clustering corresponding to species.

Achene micromorphology

SEM analyses

Micromorphological characteristics were assessed using scanning electron microscopy (SEM) and stereomicroscope observations. Micromorphological observations revealed variation among the 13 species examined by SEM, particularly in surface ornamentation, epidermal cell morphology, and periclinal and anticlinal wall characteristics (Figures 6-9, Table 1). In contrast, several general characters were relatively uniform. Most species possessed achenes ranging from ovate to ovate-globose, all had a subbasal hilum and achene colour varied only from light yellow to golden, with a distinct glossy surface.

Apex type

Three apex types were distinguished. The most numerous group was the acute-curved type, which included *A. propinqua, A. glaucescens, A. glabra, A. gracilis, A. crinita, A. walasii, A. pseudoincisa, A. plicata, A. obtusa* and *A. subcrenata*. The acute type was found in *A. glabra, A. glabricaulis, A. glaucescens, A. gorcensis, A. acutiloba, A. gracilis* and *A. xanthochlora*. The blunt-acuminate type was recorded in *A. monticola* and *A. glabricaulis*. For several species, the assignment was ambiguous. In *A. glabra*, examined vouchers with both acute-curved and acute apex types were

recorded. Similarly, in *A. glabricaulis*, examined material with both blunt-acuminate and acute apex types were found.

Achene surface

Three types of achene surface were recognized (Figure 6A-C). Type 1, characterized by irregular reticulate elevations (Figure 6A), included three species: *A. acutiloba, A. gorcensis* and *A. plicata*. The majority of species belonged to Type 2, characterized by uneven and irregular fine elevations (Figure 6B) and included *A. xanthochlora, A. crinita, A. glabra, A. glaucescens, A. gracilis, A. monticola, A. propinqua, A. subcrenata* and *A. walasii*. Type 3, characterized by ruminate elevations and depressions (Figure 6C), was recorded exclusively in *A. subglobosa*.

Achene sculpture

Two main sculpture types were recognized (Figure 7A,B). The most common sculpture type was reticulate (Figure 7A), occurring in *A. acutiloba, A. crinita, A. glabra, A. glaucescens, A. gorcensis, A. gracilis, A. monticola, A. plicata, A. subcrenata* and *A. subglobosa*. The colliculate type (Figure 7B) was represented by three species: *A. propinqua, A. walasii* and *A. xanthochlora*. In addition to surface ornamentation, the examined taxa also differed in epidermal cell morphology and cell wall characteristics.

Epidermal cell shape

The studied species exhibited three epidermal cell shape categories (Figure 8A-C). Polygonal cells (Figure 8A) were observed in *A. acutiloba, A. crinita, A. gorcensis* and *A. subglobosa*. Polygonal-irregular cells (Figure 8B) occurred in *A. glaucescens,*

A. gracilis, A. monticola, A. subcrenata, A. walasii and *A. xanthochlora*, whereas elongated polygonal-irregular cells (Figure 13C) were found in *A. glabra, A. plicata* and *A. propinqua*.

Epidermal cell wall characteristics

Epidermal cell wall type

Most species possessed straight anticlinal walls (Figure 9A), whereas undulate anticlinal walls (Figure 9B) were observed in *A. gracilis, A. subcrenata, A. walasii* and *A. xanthochlora*.

Periclinal cell walls

Two types of periclinal cell walls were distinguished: raised (Type 1; Figure 9C) and depressed (Type 2). The depressed type was recorded only in *A. subglobosa*.

Anticlinal cell walls

Most species were characterized by depressed anticlinal cell walls (Figure 9D), whereas raised anticlinal walls were observed exclusively in *A. subglobosa*.

Overall, the examined micromorphological characters showed greater intraspecific differentiation than achene shape. Although most species shared similar achene shape and hilum position, surface ornamentation, epidermal cell morphology and cell wall structure exhibited clear interspecific differences. Among the taxa examined by SEM, *A. subglobosa* exhibits the most distinctive combination of micromorphological characters, including Type 3 surface ornamentation, epidermal cell morphology and depressed periclinal walls, and raised anticlinal wall.

Integrated macro- and micromorphological differentiation

The integrated analysis of quantitative achene-shape descriptors and micromorphological characters revealed multivariate structuring among the examined vouchers (Figure 10). Four species (*A. glabricaulis*, *A. hirsuticaulis*, *A. obtusa*, and *A. pseudoincisa*) were not represented in the integrated analysis because the required SEM data were unavailable. *Alchemilla subglobosa* was retained despite missing information for apex type because the remaining micromorphological characters provided informative data for this voucher.

The resulting Gower distance matrix was analyzed using principal coordinates analysis (PCoA) with Lingoes correction. In the current analysis, the first two principal coordinates accounted for 18.28% of the total variation (10.62% and 7.66%, respectively), while the first ten axes accounted for 41.45%. The PCoA therefore provided an ordination of herbarium vouchers based on the combined phenotypic information, including both achene shape and SEM-derived surface characteristics.

To investigate which characteristics were associated with the PCoA configuration, environmental fitting (envfit) was performed.

Among the quantitative shape variables, aspect ratio ($r^2 = 0.115$, $p = 0.0243$), solidity ($r^2 = 0.108$, $p = 0.0274$), and PC2 of the EFDs ($r^2 = 0.095$, $p = 0.042$) showed significant associations with the first two PCoA axes. In contrast, circularity, and PC1 of the EFDs were not significantly associated with the ordination ($p = 0.5823$ and $p = 0.2075$, respectively).

Nevertheless, several SEM-derived characteristics showed substantially stronger associations with the PCoA configuration. Epidermal cell shape was particularly strongly associated with the ordination, including the polygonal-irregular category ($r^2 = 0.887$, $p < 0.001$), polygonal cells ($r^2 = 0.488$, $p < 0.001$), and elongated polygonal-

irregular cells ($r^2 = 0.423$, $p < 0.001$). The strongest association was observed for the acute-curved category ($r^2 = 0.899$, $p < 0.001$), followed by the acute category ($r^2 = 0.464$, $p < 0.001$) and the blunt-acuminate category ($r^2 = 0.439$, $p < 0.001$). Among the categorical surface characteristics, surface type showed the strongest association, with the first two PCoA axes ($r^2 = 0.328$, $p < 0.001$), followed by anticlinal wall pattern ($r^2 = 0.229$, $p < 0.001$) and sculpture ($r^2 = 0.107$, $p = 0.001$). Periclinal and anticlinal relief were not significantly associated with the first two PCoA axes (both $p = 1$).

The PCoA configuration showed stronger associations with several SEM-derived characteristics, particularly epidermal cell shape, apex morphology, surface type, and anticlinal wall pattern. Among the quantitative achene-shape variables, only aspect ratio, solidity, and EFD PC2 were significantly associated with the first two PCoA axes. The results indicate that, within the variation represented by the first two PCoA axes, several SEM characteristics showed stronger associations with the ordination than most quantitative achene-shape variables.

To assess whether species identity was associated with the full phenotype, including both achene shape and SEM-derived characteristics, a PERMANOVA was conducted using a common dataset of 66 complete samples representing 12 species (Table 2). The analysis showed a significant effect of species identity ($R^2 = 0.832$, $F = 24.326$, $p < 0.001$, 9,999 permutations), with species identity accounting for 83.2% of the variation in the combined phenotypic distance matrix. The corresponding PERMDISP test was significant ($F = 2.082$, $p = 0.0437$), again indicating heterogeneity in within-species multivariate dispersion.

To assess the relative contribution of the two types of phenotypic characteristics, separate PERMANOVA analyses were performed. Shape characteristics alone showed a significant but comparatively weaker association with species identity ($R^2 = 0.249$, $F = 1.625$, $p = 0.0415$, 9999 permutations). PERMDISP test was not significant ($F = 0.846$, $p = 0.5992$), indicating no evidence of differences in within-species multivariate dispersion among species for the shape dataset. Whereas SEM-derived characteristics showed a substantially stronger association ($R^2 = 0.904$, $F = 45.992$, $p < 0.001$, 9999 permutations).

The SEM-derived characteristics therefore showed the strongest association with species identity among the three datasets, consistent with the pattern observed for the combined phenotype. However, the PERMDISP test was also significant ($F = 2.229$, $p = 0.0313$), indicating differences in within-species multivariate dispersion among species. Thus, the strong PERMANOVA result for the SEM dataset should be interpreted in the context of both differences in multivariate location and differences in dispersion.

Environmental associations of achene morphology

Finally, we assessed whether climatic and soil conditions were associated with the observed variation in achene morphology.

For the RDA based on WorldClim climatic variables, BIO4, BIO12, and BIO15 were selected, together with soil variables: AWC, bulk density, C:N ratio, coarse fragment content, K, and pH, after removing highly correlated variables using a correlation threshold of 0.7 (see methods).

A full RDA including both climatic and soil variables was performed, and partial RDAs were used to assess the unique contributions of climatic and soil variables after

controlling for the other predictor group. The combined RDA model (Figure 11; Table S4) explained 13.64% of the total variation in the shape data ($R^2 = 0.136$), whereas the adjusted R^2 was only 0.002. The overall model was not statistically significant (permutation test, 9999 permutations; $F = 1.018$, $p = 0.449$).

When individual predictors were added sequentially, BIO12 was the only predictor reaching statistical significance ($F = 2.439$, $p = 0.045$), whereas BIO4, BIO15, AWC, bulk density, C:N ratio, coarse fragment content, K, and pH were not significant ($p > 0.05$). However, none of the predictors showed a significant marginal effect after accounting for the other variables ($p > 0.05$). Variance inflation factors ranged from 1.10 to 3.46, indicating no severe multicollinearity among the explanatory variables.

Partial RDA showed that climatic variables explained 5.15% of the total variation after controlling for soil variables, but this effect was not significant ($F = 1.152$, $p = 0.316$; adjusted $R^2 = 0.007$). Soil variables explained 6.8% of the variation after controlling for climatic variables, and this effect was also not significant ($F = 0.761$, $p = 0.794$; adjusted $R^2 = -0.022$). Variance partitioning indicated that the unique fraction attributable to climate accounted for 0.75% of the variation (adjusted $R^2 = 0.007$), whereas the unique soil fraction was negative (adjusted $R^2 = -0.022$), indicating no additional explanatory power of soil variables after accounting for climatic variables.

Variance partitioning yielded a small unique climate fraction (adjusted $R^2 = 0.007$), a negative unique soil fraction (adjusted $R^2 = -0.022$), and a small shared fraction (adjusted $R^2 = 0.017$) (Table S4).

Thus, climatic variation showed only a weak association with achene morphological variation and explained little of the total variation after adjustment, whereas no detectable association with the examined soil variables was found. The geographic distribution of the herbarium material used in the study is shown in Figure 12. Sampling

locations were distributed across Poland, although their distribution was uneven, with a substantial proportion of the examined material originating from northern Poland.

Discussion

Morphometry

Achene morphology shows slight differences among the studied *Alchemilla* species. However, the overall level of differentiation is relatively low. Both the voucher-level PCA based on conventional shape descriptors and EFD-derived variables and the EFD analysis of achene contours showed substantial overlap among species, with no clear species-specific groups. The reconstructed EFD contours likewise indicated largely continuous variation in achene outline rather than discrete species-specific patterns. Taken together, these results indicate that quantitative achene shape provides limited discriminatory power among the examined *Alchemilla* taxa.

Quantitative achene shape has not been widely investigated as a source of taxonomic information. Nevertheless, several studies have demonstrated its potential for distinguishing taxa at different taxonomic levels. Studies conducted across diverse angiosperm groups indicate that the taxonomic value of fruit shape varies considerably among lineages and is often greatest when combined with additional morphological characters. Within Rosaceae, achene morphology has been examined in the genus *Rosa* L. (Jagodziński et al., 2016), although these analyses have generally incorporated additional characters related to surface micromorphology. Similarly, studies of *Taraxacum* F.H.Wigg. (Asteraceae) have shown that the combined analysis of achene shape and other morphological characters provides valuable taxonomic information and improves the discrimination of taxa within the group (Rewicz et al., 2020).

Fruit shape alone has also been investigated in Lamiaceae, where nutlets were shown to differ markedly among genera and tribes, as well as among some species (Gutiérrez del Pozo et al., 2025). In certain genera, fruit or seed shape may be of greater taxonomic value. For example, studies of *Rheum* L. (Polygonaceae) in Kazakhstan have shown that differences in fruit morphology can facilitate the discrimination of particular taxonomic

groups (Sumbembayev et al., 2023). However, the limited availability of comparable studies makes it difficult to assess the overall taxonomic utility of fruit and seed shape across different plant groups. Moreover, the potential influence of phenotypic plasticity on achene morphology within taxa cannot be excluded.

The substantial overlap among vouchers and species observed in both conventional shape descriptors and EFD-derived contour variation indicates considerable variation in achene shape within the examined taxa. Because multiple achenes originating from the same herbarium voucher were treated as subsamples rather than as independent biological replicates, the present analyses do not provide a direct quantitative partitioning of variation into intra-individual, intra-population, and interspecific components. Nevertheless, the extensive overlap among species indicates that achene shape alone is insufficient for reliable discrimination of the examined *Alchemilla* taxa. Such a result is not unexpected when considering the biology of *Alchemilla*.

Many species form taxonomically complex groups and their morphological characters often exhibit a continuum rather than clear discontinuities between taxa (Sepp & Paal, 1998). This complexity associated with the widespread occurrence of apomixis, together with documented polyploidization and hybridization events, which have contributed to the evolution of numerous microspecies within the genus (Cervantes-Díaz et al., 2024; Morales-Briones et al., 2022; Pihu et al., 2009; Rono et al., 2020; Sepp et al., 2000).

Although the processes underlying the observed patterns cannot be fully disentangled, the present environmental analyses allow the potential contribution of climatic and soil variation to be assessed more directly. Climatic variables showed only a weak overall association with achene morphological variation, with a very small proportion

of variation explained after adjustment, whereas no significant association was detected for the examined soil variables. However, the available achene material represented a geographically restricted set of sampling locations, concentrated mainly in northern Poland, where climatic conditions may be relatively homogeneous. The resulting limited environmental variation may have reduced the ability to detect relationships between environmental conditions and achene morphology. Thus, the observed morphological overlap cannot be readily attributed to the environmental gradients considered here, although effects of environmental factors not captured by the present dataset cannot be excluded. Although comparable evidence is still lacking for *Alchemilla* and, more broadly, for Rosaceae, studies from other plant families suggest that both environmental and genetic factors may contribute to variation in fruit morphology. For example, morphometric traits of the achenes of *Heterosperma pinnatum* Cav. (Asteraceae) have been shown to vary across different geographical regions, indicating a relationship between achene morphology and environmental conditions (Venable et al., 1998). At the same time, some of these traits have also been demonstrated to possess a genetic basis and to remain stable within populations (Venable & Búrquez, 1989). In the genus *Lappula* Moench (Boraginaceae), nutlet shape has been shown to respond to abiotic environmental factors and to vary under environmental stress (Lu et al., 2013), which may explain the high level of macromorphological variation observed within the genus (Ebadi & Nikzat, 2021; Liu et al., 2025; Ma et al., 2010). Similarly, seed heteromorphism in *Aethionema arabicum* (L.) Andrz. ex Rchb. (Brassicaceae) has been interpreted as an adaptive response to changing environmental conditions, illustrating the potential role of phenotypic plasticity in seed morphology (Lenser et al., 2016). In *Rheum* (Polygonaceae), fruit shape has likewise been found to correlate with environmental variables (Sumbembayev

et al., 2023), suggesting that environmental conditions may represent an important, although still insufficiently understood, driver of fruit morphology. In contrast, micromorphological characters, particularly those related to the surface structure of fruits and seeds, are generally considered to be more stable and therefore may provide more reliable taxonomic information (Ebadi & Nikzat, 2021; Krawczyk & Głowacka, 2015; Rewicz et al., 2025; Zareh, 2024). Overall, the present results suggest that achene macromorphology alone provides limited taxonomic resolution within the studied taxa.

Micromorphology

Compared with achene macromorphology, micromorphological characters exhibited substantially greater discriminatory power, suggesting that surface ultrastructure provides a more informative source of taxonomic evidence within the studied group. Most species shared similar achene shape and hilum position, whereas surface ornamentation, epidermal cell morphology and sculpture patterns exhibited greater variation. Among the taxa examined by SEM, *A. subglobosa* showed the most distinctive combination of micromorphological characters, differing from the remaining taxa particularly in achene surface type, periclinal and anticlinal cell wall characteristics. These observations indicate that micromorphological characters are considerably more informative than achene shape alone and may provide valuable supplementary evidence for distinguishing closely related taxa.

Interestingly, despite the generally low interspecific differentiation observed in achene shape, several micromorphological features showed clearer differentiation among taxa than quantitative achene-shape characters. This suggests that surface ultrastructure may retain taxonomic information even when macromorphological characters show extensive overlap.

This pattern was further supported by the integrated analysis combining quantitative achene-shape descriptors with micromorphological characters. In the Gower-based ordination, several SEM-derived traits, particularly epidermal cell shape, apex morphology, surface type, and anticlinal wall pattern, and sculpture showed stronger associations with the multivariate configuration than most quantitative shape descriptors. Similarly, the separate PERMANOVA analyses indicated a substantially stronger association between species identity and micromorphological characters than between species identity and quantitative achene shape. These results provide quantitative support for the greater discriminatory potential of micromorphological characters observed in the qualitative comparisons.

Our results are broadly consistent with those reported by Shokatyari et al. (2022), who investigated achene micromorphology in 21 Iranian *Alchemilla* species. Similar to our findings, they demonstrated that although several achene micromorphological characters, particularly surface ornamentation, sculpture patterns, epidermal cell morphology and hilum position, are taxonomically informative, multivariate analyses revealed a close affinity among most studied species. Moreover, the resulting species groupings showed only limited agreement with the current classification, suggesting that achene morphology alone provides insufficient resolution to reflect relationships within the genus. Together with our results, these findings indicate that *Alchemilla* species exhibit relatively low interspecific differentiation in achene morphology, while selected micromorphological traits may serve as valuable supplementary characters for species delimitation.

The agreement between both studies is particularly noteworthy because they were conducted on geographically distant floras representing different subsets of the genus. Despite these differences in sampling, both investigations reached remarkably similar

conclusions regarding the generally limited interspecific variation in achene morphology and the comparatively greater taxonomic value of selected micromorphological characters. This consistency suggests that the observed patterns may not be restricted to a particular regional flora and could represent a broader characteristic of the genus.

Among the taxa examined by SEM, *A. subglobosa* showed a distinctive combination of states in several micromorphological characters. This finding suggests that the combination of surface ornamentation, epidermal cell morphology and cell wall structure may be particularly informative for recognizing morphologically distinctive taxa, even when most species remain highly similar. However, broader taxonomic sampling will be necessary to determine whether this pattern is unique to *A. subglobosa* or reflects a more general trend within the genus.

Cytogenetic variation may represent an additional source of micromorphological variation that could not be evaluated in the present study. Polyploidy and genome size are known to influence plant cell dimensions, and positive relationships between genome size and epidermal cell size have been demonstrated across angiosperms as well as within diploid-polyploid comparisons (Beaulieu et al., 2008; Sugiyama, 2005; Šmarda et al., 2023). Given the widespread occurrence of polyploidy in *Alchemilla*, variation in ploidy level could therefore potentially contribute to some of the differences in epidermal cell morphology observed among the examined taxa. However, ploidy levels were not determined for the individual herbarium vouchers analyzed here, and our data do not allow this hypothesis to be tested directly. Moreover, the available evidence primarily concerns cell dimensions rather than the specific surface ornamentation and cell-wall characters examined in the present study.

Future analyses combining achene micromorphology with genome-size or chromosome-count data would therefore be valuable for assessing this relationship. The results of studies on other groups within Rosaceae indicate that micromorphological characters, particularly those related to the surface structure of fruits and seeds, generally possess greater taxonomic value than macromorphological traits. This is especially important because fruits in many genera exhibit a high degree of similarity in both shape and size. Such patterns have been reported for the genera *Geum* L. (Faghir et al., 2015), *Potentilla* L. (Sadeghi et al., 2021) and *Rosa* (Jagodziński, 2016), as well as for representatives of the tribe Sorbarieae (Song & Hong, 2020), where surface micromorphological characters have proven to be more informative for taxonomic discrimination.

The potential taxonomic usefulness of achene micromorphology in *Alchemilla* is consistent with the long-standing use of surface micromorphological characters in plant systematics, where some epidermal and surface features have been regarded as comparatively stable and taxonomically informative, as originally emphasized by Barthlott (1981). The taxonomic significance of these characters has also been supported by more recent studies integrating micromorphological data with phylogenetic evidence, for example in the genera *Arenaria* Ruppius *ex* L. (Sadeghian et al., 2014) or *Impatiens* Riv. *ex* L. (Song et al., 2022).

Implications for taxonomy and future research

The present study provides the first comprehensive assessment of achene macro- and micromorphological diversity in *Alchemilla* from Central Europe. Although the results demonstrate the limited taxonomic value of achene macromorphology and the greater usefulness of selected micromorphological characters, several important questions

remain unresolved. The environmental analyses performed here detected only a weak association between climatic variation and achene morphology and no significant association with the examined soil variables. However, the low explanatory power of the climatic model and the restricted sampling available for these analyses mean that environmental effects on achene morphology cannot be excluded. Likewise, the phylogenetic relationships among many *Alchemilla* taxa are still insufficiently resolved, making it difficult to distinguish whether the high morphological similarity observed among species reflects close evolutionary relationships, extensive phenotypic plasticity, or a combination of both processes. Interpretation of these patterns is further complicated by the reproductive and evolutionary complexity of the genus, including widespread apomixis, polyploidy, and documented hybridization, which may contribute to discordance among different sources of taxonomic evidence.

Another limitation of the present study is the restricted taxonomic and geographical sampling. Although the investigated species represent the diversity of the genus in Poland, broader sampling across the distribution range of *Alchemilla* will be necessary to determine whether the observed patterns are consistent throughout the genus.

Future studies should therefore integrate achene micromorphology with molecular phylogenetic data, broader geographical sampling and analyses of environmentally contrasting populations. Sampling should also be expanded to include a substantially larger number of taxa, particularly representatives of different taxonomic sections and geographically distant populations. Such an integrative approach would allow the relative contributions of evolutionary history and environmental conditions to achene variation to be disentangled and would provide a more robust framework for evaluating the systematic significance of achene characters.

Common garden or cultivation experiments could additionally help distinguish genetically determined variation from environmentally induced phenotypic plasticity.

Conclusion

This study represents the first comprehensive assessment of achene macro- and micromorphology in Central European representatives of *Alchemilla*. Our results demonstrate that achene macromorphology exhibits only limited taxonomic value because quantitative analyses of achene shape revealed substantial overlap among species and no clear species-specific patterns. In contrast, selected micromorphological characters, particularly surface ornamentation and epidermal cell features, provide useful supplementary evidence for species delimitation, although they should not be used in isolation. The integrated analysis further supported this pattern, showing that micromorphological characters contributed more strongly to differentiation among the examined taxa than quantitative achene-shape descriptors. Together with previous evidence from Iranian species, our findings suggest that low interspecific differentiation in achene morphology may extend across geographically distinct groups of *Alchemilla*, although broader taxonomic and geographical sampling is required to determine how widely this pattern occurs within the genus. Future studies integrating micromorphology, molecular phylogenetics and broader geographical sampling will be essential for evaluating the systematic significance of these characters.

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Tables

Table 1. Comparison of achene apex type, surface features, epidermal cell morphology, cell wall characteristics, and surface sculpture among the examined *Alchemilla* taxa.

Table 1. Comparison of achene apex type, surface features, epidermal cell morphology, cell wall characteristics, and surface sculpture among the examined *Alchemilla* taxa.							
Species of *Alchemilla*	**Apex type**	**Achene surface**	**Epidermal cell shape**	**Epidermal cell wall type**	**Periclinal cell wall**	**Anticlinal cell wall**	**Achene sculpture**
A. acutiloba	acute	irregular reticulate elevations	polygonal	straight	raised	depressed	reticulate
A. crinita	acute-curved	uneven and irregular fine elevations	polygonal	straight	raised	depressed	reticulate
A. glabra	acute, acute-curved	uneven and irregular fine elevations	long polygonal-irregular	straight	raised	depressed	reticulate
A. gracilis	acute, acute-curved	uneven and irregular fine elevations	polygonal-irregular	undulate	raised	depressed	reticulate
A. glaucescens	acute, acute-curved	uneven and irregular fine elevations	polygonal-irregular	straight	raised	depressed	reticulate
A. gorcensis	acute	irregular reticulate elevations	polygonal	straight	raised	depressed	reticulate
A. monticola	blunt-acuminate	uneven and	polygonal-	straight	raised	depressed	reticulate

		irregular fine elevations	irregular				
A. plicata	acute-curved	irregular reticulate elevations	long polygonal-irregular	straight	raised	depressed	reticulate
A. propinqua	acute-curved	uneven and irregular fine elevations	polygonal-irregular or long polygonal-irregular	straight	raised	depressed	colliculate
A. subcrenata	acute-curved	uneven and irregular fine elevations	polygonal-irregular	undulate	raised	depressed	reticulate
A. subglobosa	acute	ruminate elevations-depressions	polygonal	straight	depressed	raised	reticulate
A. walasii	acute-curved	uneven and irregular fine elevations	polygonal-irregular	undulate	raised	depressed	colliculate
A. xanthochlora	acute	uneven and irregular fine elevations	polygonal-irregular	undulate	raised	depressed	colliculate

Table 2. PERMANOVA and PERMDISP results for quantitative achene-shape variables, SEM derived micromorphological characters, and the combined dataset.

Table 2. PERMANOVA and PERMDISP results for quantitative achene-shape variables, SEM derived micromorphological characters, and the combined dataset.					
Dataset	**PERMANOVA R^2**	**PERMANOWA F**	**p**	**PERMDISP F**	**p**
Shape only	0.249	1.625	0.0415	0.846	0.5992
SEM only	0.904	45.992	<0.001	2.229	0.0313
Shape + SEM	0.832	24.326	<0.001	2.082	0.0437

Figure captions

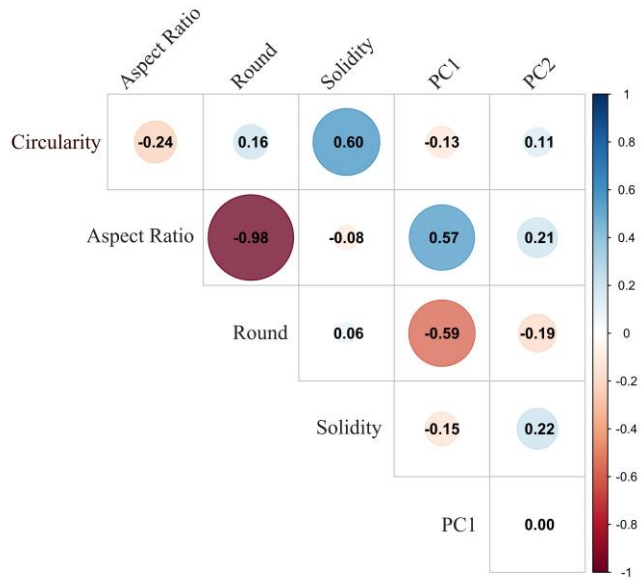


Figure 1. Pearson correlation matrix showing relationships between the first two principal component scores derived from the analysis of elliptic Fourier descriptors (PC1 and PC2) and the analyzed achene-shape indices.

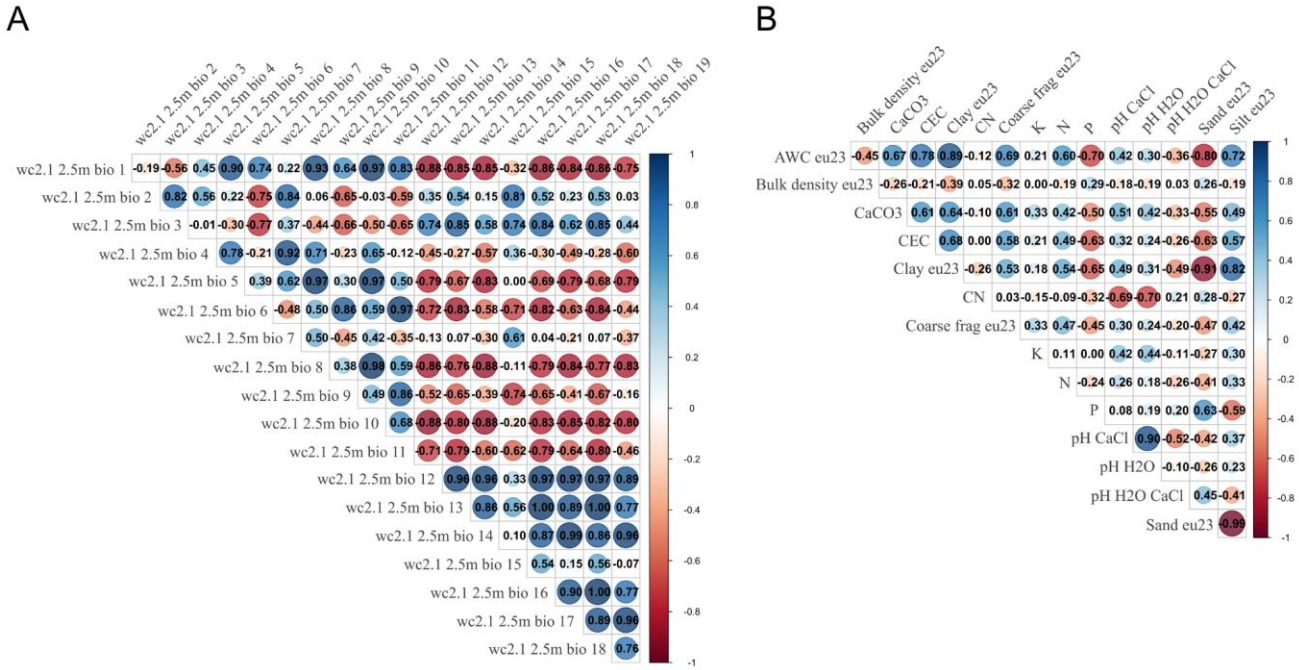


Figure 2. Pearson correlation matrices showing relationships among climatic (A) and soil (B) environmental variables used in the redundancy analysis (RDA).



Figure 3. Light microscopy images of selected *Alchemilla* achenes. (A) Close-up view of *Alchemilla glaucescens* Wallr.; (B) close up view of *Alchemilla xanthochlora* Rothm.; (C) *Alchemilla monticola* Opiz; (D) *Alchemilla crinita* Buser.

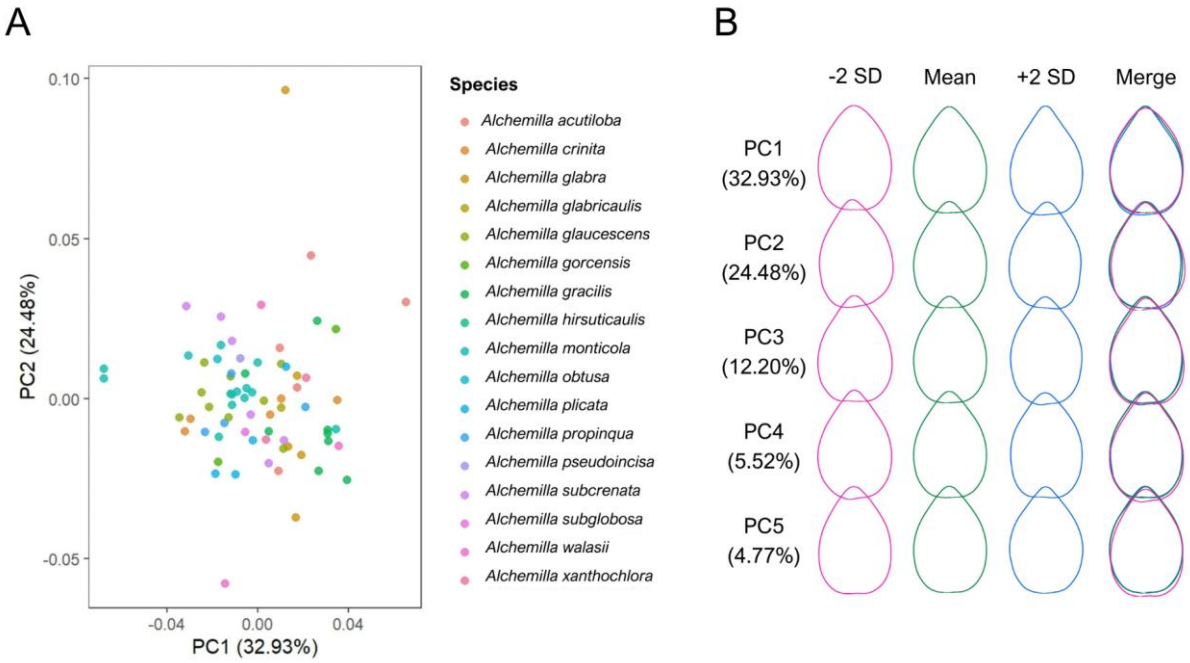


Figure 4. Principal component analysis (PCA) based on Elliptical Fourier Descriptor (EFD) coefficients of achene shape in the examined *Alchemilla* taxa: (A) ordination of specimens along the first two principal components (PC1 and PC2); (B) reconstructed achene outlines showing shape variation along PC1-PC5 at −2 SD, the mean, and +2 SD, with merged outlines shown in the rightmost column.

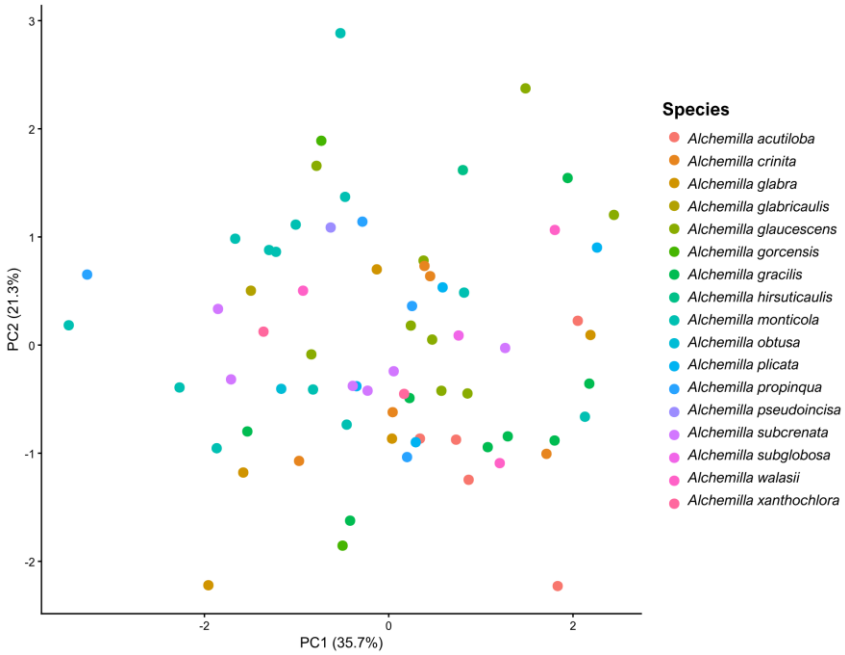


Figure 5. Principal component analysis (PCA) based on the analyzed achene-shape descriptors (aspect ratio, circularity, and solidity) and the first two principal component scores derived from Elliptical Fourier Descriptors (EFD-PC1 and EFD-PC2) in the examined *Alchemilla* taxa.

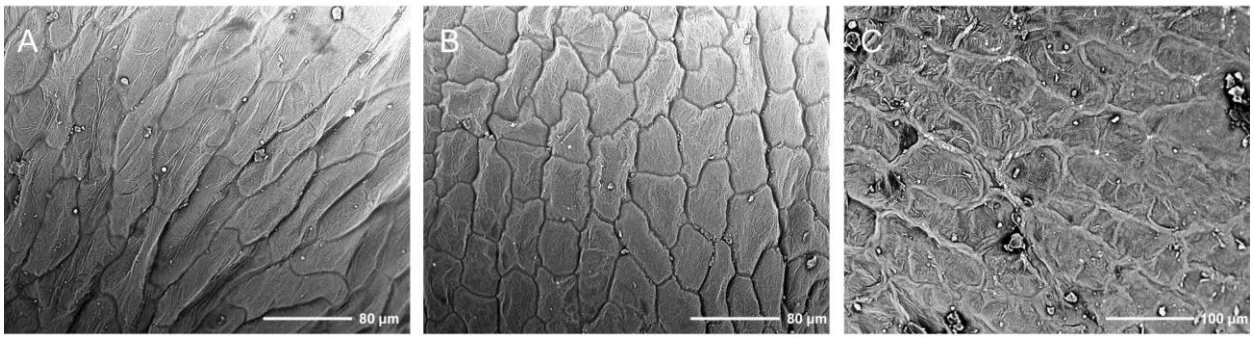


Figure 6. SEM images showing three types of achene surface ornamentation in selected *Alchemilla* taxa: (A) irregular reticulate elevations in *A. plicata*; (B) uneven and irregular fine elevations in *A. gracilis*; (C) ruminate elevations and depressions in *A. subglobosa*. Scale bars: A-B = 80 µm; C = 100 µm.

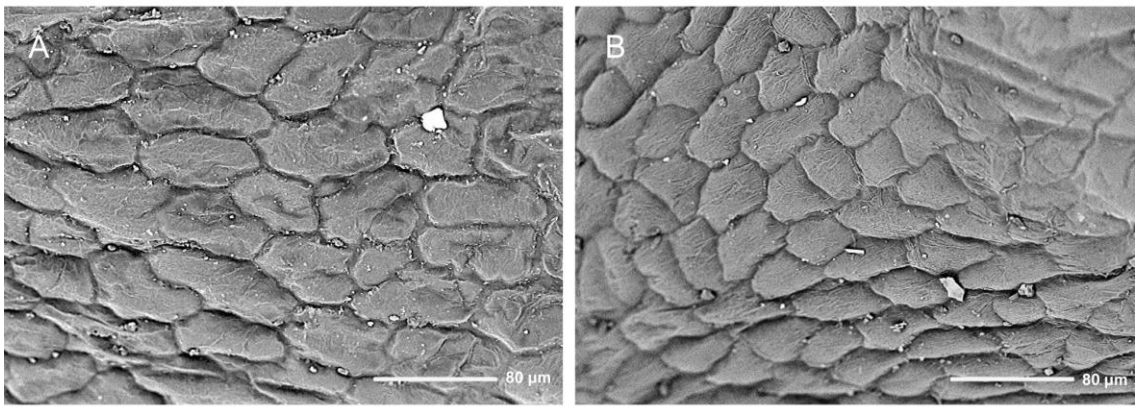


Figure 7. SEM images showing two main types of achene sculpture in selected *Alchemilla* taxa: (A) reticulate sculpture in *A. monticola*; (B) colliculate sculpture in *A. xanthochlora*. Scale bars = 80 µm.

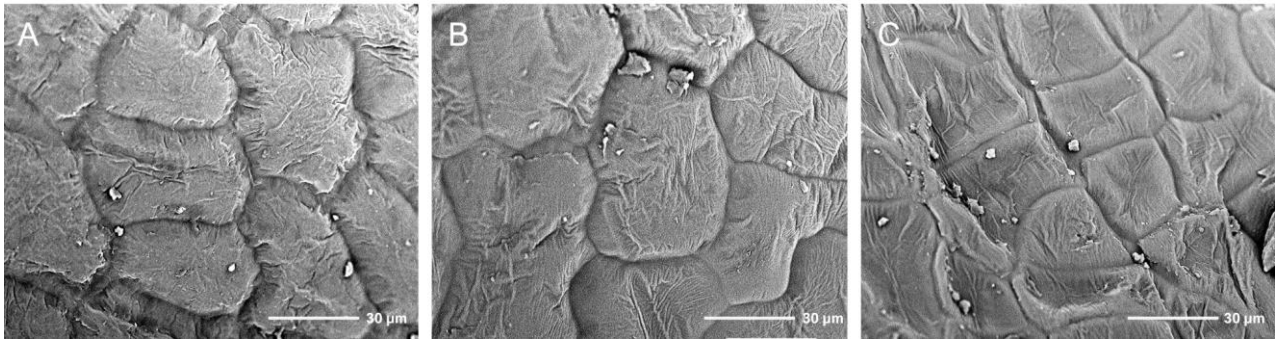


Figure 8. SEM images showing three epidermal cell shape types in selected *Alchemilla* taxa: (A) polygonal cells in *A. crinita*; (B) polygonal-irregular cells in *A. walasii*; (C) elongated polygonal-irregular cells in *A. plicata*. Scale bars = 30 µm.

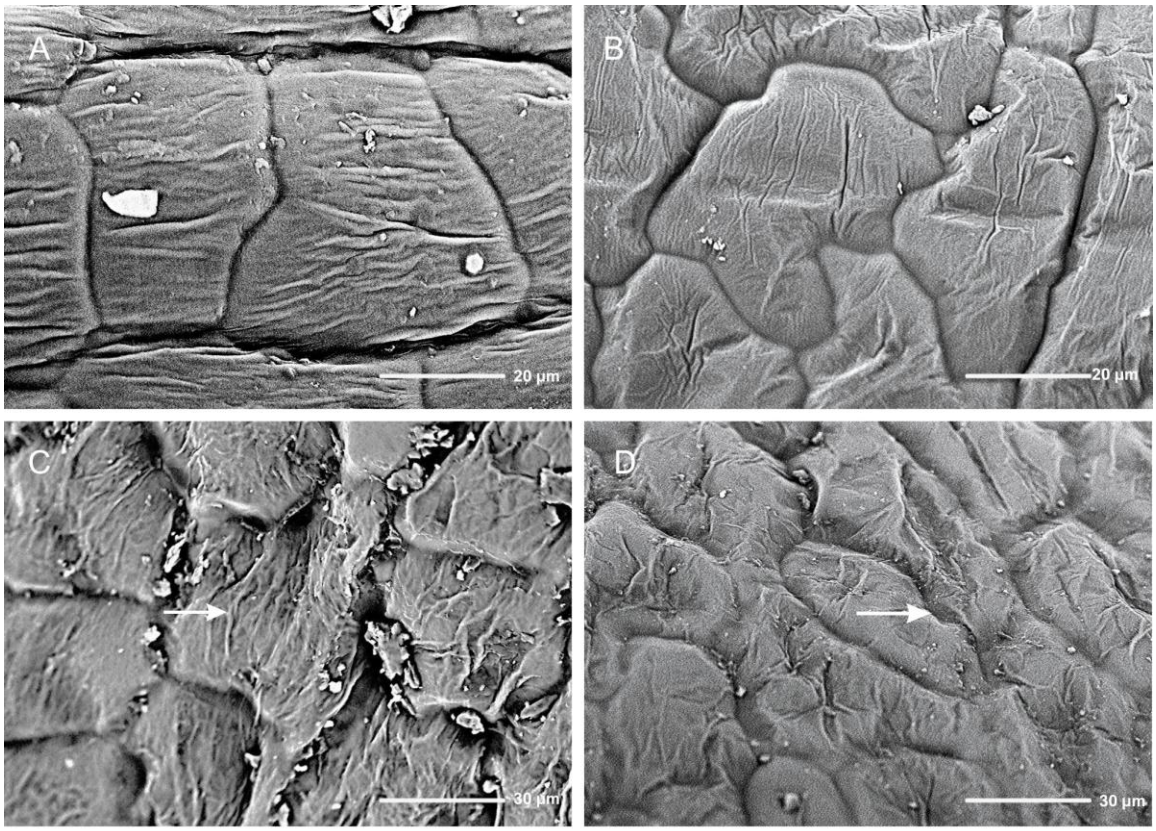


Figure 9. SEM images showing selected epidermal cell wall characteristics in *Alchemilla* taxa: (A) straight anticlinal walls in *A. gorcensis*; (B) undulate anticlinal walls in *A. gracilis*; (C) raised periclinal cell walls in *A. xanthochlora*; (D) depressed anticlinal cell walls in *A. propinqua*. Arrows indicate the respective wall characteristics in C and D. Scale bars: A-B = 20 µm; C-D = 30 µm.

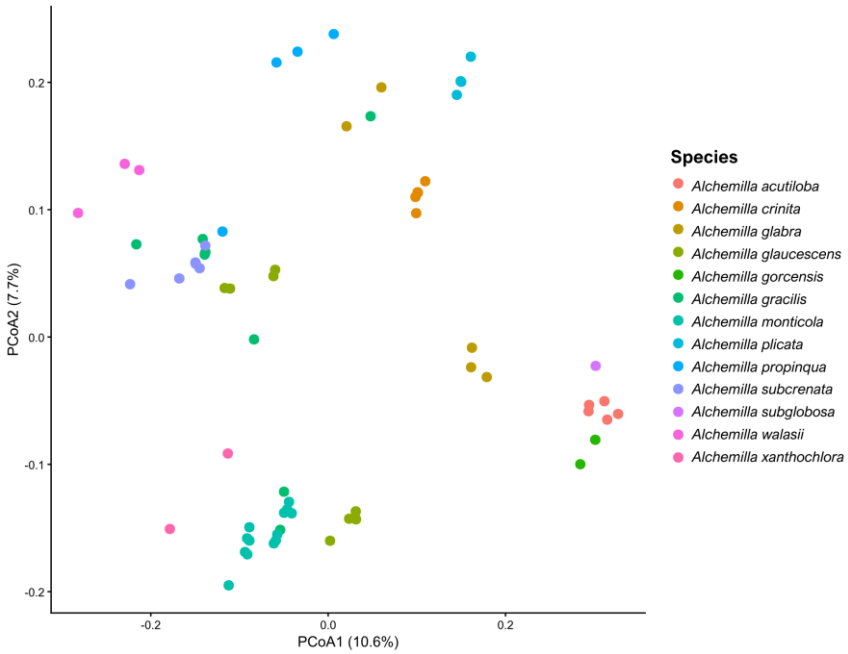


Figure 10. Principal Coordinates Analysis (PCoA) based on Gower dissimilarities calculated from combined quantitative achene-shape descriptors and qualitative micromorphological characters in the examined *Alchemilla* taxa.

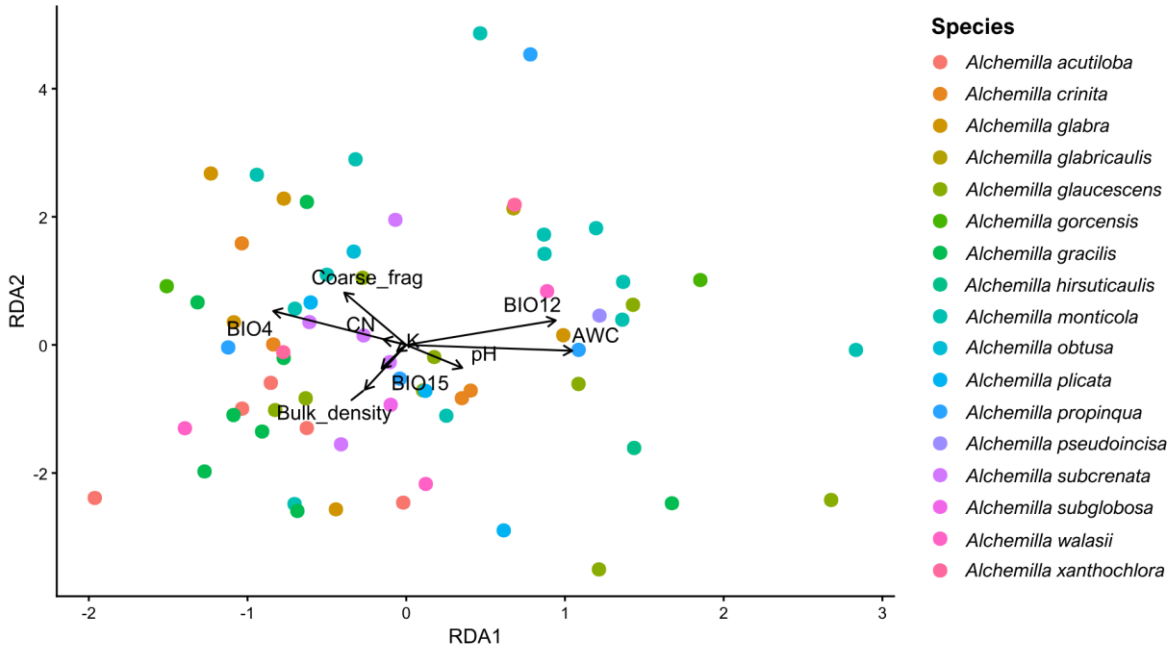


Figure 11. Full RDA ordination of achene morphological variation in relation to climatic and soil variables. Site and environmental scores are provided in Supplementary Table S4.

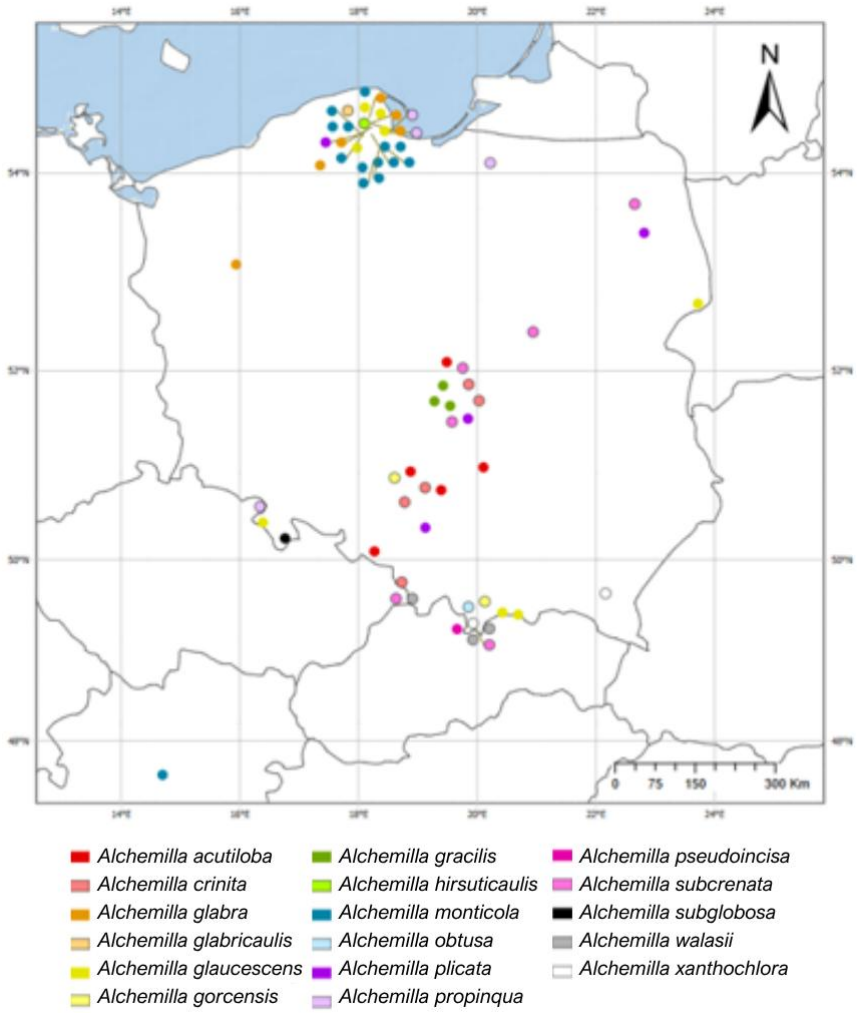


Figure 12. Geographic distribution of sampling locations represented by the *Alchemilla* material examined in the present study. Colours indicate individual species.

Supplementary materials

Table S1. List of the examined *Alchemilla* herbarium specimens, including sample IDs, voucher identifiers, and geographic coordinates.

Table S2. Results of specimen-level principal component analysis (PCA) based on normalized elliptic Fourier descriptor (EFD) coefficients describing achene outline variation in the examined *Alchemilla* taxa.

Table S3. Combined dataset used in the statistical analyses, including EFD-derived principal component scores, achene-shape descriptors, SEM-derived micromorphological characters, and environmental variables.

Table S4. Scores of climatic and soil variables on the first two axes of the redundancy analysis (RDA).

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Table S1. List of the examined *Alchemilla* herbarium specimens, including sample IDs, voucher identifiers, and geographic coordinates.

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No.	Sample ID	Species	Herbarium voucher identifier	Geographic coordinates
1	*1*	*Alchemilla monticola* Opiz	UGDA.0237704	54.450370, 18.545834
2	*2*	*Alchemilla glabricaulis* H.Lindb.	UGDA.0240514	54.5195, 18.1105
3	*3*	*Alchemilla monticola* Opiz	UGDA.0237289	54.412661, 18.099731
4	*4*	*Alchemilla monticola* Opiz	UGDA.0201600	47.6148, 14.6991
5	5	*Alchemilla hirsuticaulis* H.Lindb.	UGDA.0244400	54.4919, 18.0982
6	*6*	*Alchemilla gracilis* Walters	UGDA.0240555	54.5195, 18.1105
7	*7*	*Alchemilla gracilis* Walters	UGDA.0279385	54.276426, 18.446012
8	*8*	*Alchemilla monticola* Opiz	UGDA.0237565	54.2373, 18.3461
9	*9*	*Alchemilla monticola* Opiz	UGDA.0237564	54.266929, 18.429018
10	*10*	*Alchemilla monticola* Opiz	UGDA.0269771	54.7994, 18.1111
11	*11*	*Alchemilla glaucescens* Wallr.	UGDA.0270748	50.4, 16.3888
12	*12*	*Alchemilla glabra* Neygenf.	UGDA.0023970	54.5536, 18.1869
13	*13*	*Alchemilla glabra* Neygenf.	UGDA.0023971	54.4564, 18.2236
14	*14*	*Alchemilla monticola* Opiz	UGDA.0023982	54.3672, 18.0814
15	*15*	*Alchemilla monticola* Opiz	UGDA.0023981	54.1828, 18.3297
16	*16*	*Alchemilla monticola* Opiz	UGDA.0023980	54.4808, 17.9772
17	*17*	*Alchemilla monticola* Opiz	UGDA.0023978	54.1058, 18.2481
18	*18*	*Alchemilla monticola* Opiz	UGDA.0023977	54.0589, 18.1289
19	*19*	*Alchemilla monticola* Opiz	UGDA.0023974	54.4601, 17.8427
20	*20*	*Alchemilla monticola* Opiz	UGDA.0023973	54.3861, 18.2211
21	*21*	*Alchemilla propinqua* H.Lindb.	UGDA.0237577	54.104, 20.2202
22	*22*	*Alchemilla propinqua* H.Lindb.	UGDA.0237582	54.404081, 18.515965
23	*23*	*Alchemilla propinqua* H.Lindb.	UGDA.0237580	50.4846, 16.3414
24	*24*	*Alchemilla propinqua* H.Lindb.	UGDA.0237575	54.3988, 18.4811
25	*25*	*Alchemilla plicata* Buser	UGDA.0279364	54.3942, 18.0779
26	*26*	*Alchemilla glaucescens* Wallr.	UGDA.0279392	49.4246, 20.4267
27	*27*	*Alchemilla glaucescens* Wallr.	UGDA.0279390	49.401, 20.5794
28	*28*	*Alchemilla glaucescens* Wallr.	UGDA.0279393	52.6905, 23.7215
29	*29*	*Alchemilla glaucescens* Wallr.	UGDA.0237401	54.2527, 17.9773
30	*30*	*Alchemilla glaucescens* Wallr.	UGDA.0279394	54.588, 18.3245
31	*31*	*Alchemilla glabra* Neygenf.	UGDA.0114798	54.4885, 18.2199
32	*32*	*Alchemilla glabra* Neygenf.	UGDA.0269110	53.0893, 15.9384
33	*33*	*Alchemilla glabra* Neygenf.	UGDA.0229338	54.4979, 18.221
34	*34*	*Alchemilla gracilis* Walters	UGDA.0114795	54.0796, 17.3553
35	*35*	*Alchemilla gracilis* Walters	UGDA.0279384	54.276426, 18.446012
36	*36*	*Alchemilla glaucescens* Wallr.	UGDA.0279391	49.401, 20.5794
37	*43*	*Alchemilla gorcensis* Pawl.	LOD.154149	49.544697, 20.129271
38	*44*	*Alchemilla gorcensis* Pawl.	LOD.060398	50.877445, 18.608436
39	*45*	*Alchemilla acutiloba* Opiz	LOD.156252	50.919685, 18.689729
40	*46*	*Alchemilla acutiloba* Opiz	LOD.156251	50.088864, 18.270405
41	*47*	*Alchemilla acutiloba* Opiz	LOD.156230	50.747211, 19.229886
42	*48*	*Alchemilla acutiloba* Opiz	LOD.155167	50.988974, 20.106429
43	*49*	*Alchemilla acutiloba* Opiz	LOD.154803	52.090741, 19.488063
44	*50*	*Alchemilla gracilis* Walters	LOD.005707	51.846843, 19.425656
45	*51*	*Alchemilla gracilis* Walters	LOD.005708	51.831313, 19.421796
46	*52*	*Alchemilla gracilis* Walters	LOD.005709	51.635773, 19.545013
47	*53*	*Alchemilla gracilis* Walters	LOD.005710	51.602968, 19.499300
48	*54*	*Alchemilla crinita* Buser	LOD.155739	51.712715, 20.031485
49	*55*	*Alchemilla crinita* Buser	LOD.006788	50.618772, 18.779142
50	*56*	*Alchemilla crinita* Buser	LOD.055150	49.705119, 18.729628
51	*57*	*Alchemilla crinita* Buser	LOD.058369	50.773504, 19.124247
52	*58*	*Alchemilla crinita* Buser	LOD.153111	51.859566, 19.857419
53	*59*	*Alchemilla walasii* Pawl.	LOD.060402	49.271043, 19.982406
54	*60*	*Alchemilla walasii* Pawl.	LOD.060403	49.290053, 20.012212
55	*61*	*Alchemilla walasii* Pawl.	LOD.052483	49.576287, 18.908244

56	*62*	*Alchemilla xanthochlora* Rothm.	LOD.006707	49.305426, 19.931244
57	*63*	*Alchemilla xanthochlora* Rothm.	LOD.006693	49.633280, 22.163316
58	*64*	*tlchemilla subglobosa* C.G.Wester	LOD.060461	50.230385, 16.762186
59	*65*	*Alchemilla pseudoincisa* Pawl.	LOD.060404	49.242663, 19.893149
60	*66*	*Alchemilla plicata* Buser	LOD.060512	53.407287, 22.814365
61	*67*	*Alchemilla plicata* Buser	LOD.056724	50.345082, 19.127397
62	*68*	*Alchemilla plicata* Buser	LOD.005857	51.501198, 19.845678
63	*69*	*Alchemilla obtusa* Buser	LOD.060400	49.307398, 19.936202
64	*70*	*Alchemilla subcrenata* Buser	LOD.080927	53.695928, 22.655276
65	*71*	*Alchemilla subcrenata* Buser	LOD.060455	52.401863, 20.943758
66	*72*	*Alchemilla subcrenata* Buser	LOD.006764	49.705143, 18.729267
67	*73*	*Alchemilla subcrenata* Buser	LOD.006763	51.507127, 19.713634
68	*74*	*Alchemilla subcrenata* Buser	LOD.006761	49.283694, 19.952606
69	*75*	*Alchemilla subcrenata* Buser	LOD.006759	51.838361, 19.749411
70	*76*	*Alchemilla glaucescens* Wallr.	UGDA.0202305	54.417972, 18.44225
71	*77*	*Alchemilla glaucescens* Wallr.	UGDA.0109015_2	54.6153, 18.1105

Table S2. Results of specimen-level principal component analysis (PCA) based on normalized elliptic Fourier descriptor (EFD) coefficients describing achene outline variation in the examined *Alchemilla* taxa.

Table S2. Results of specimen-level principal component analysis (PCA) based on normalized elliptic Fourier descriptor (EFD) coefficients describing achene outline variation in the examined *Alchemilla* taxa.

A. Specimen-level PC1 and PC2 scores

No.	Sample ID	Species	PC1	PC2
1	1	*Alchemilla monticola* Opiz	-0.01142702	-0.00203110
2	2	*Alchemilla glabricaulis* H.Lindb.	0.01029835	-0.00292357
3	3	*Alchemilla monticola* Opiz	-0.01622599	0.01676640
4	4	*Alchemilla monticola* Opiz	-0.00256721	0.00183267
5	5	*Alchemilla hirsuticaulis* H.Lindb.	-0.01196134	0.00150900
6	6	*Alchemilla gracilis* Walters	0.02606789	0.02426544
7	7	*Alchemilla gracilis* Walters	-0.00544452	0.00766808
8	8	*Alchemilla monticola* Opiz	0.03454953	-0.00968050
9	9	*Alchemilla monticola* Opiz	-0.01126214	0.00119103
10	10	*Alchemilla monticola* Opiz	-0.06795881	0.00928293
11	11	*Alchemilla glaucescens* Wallr.	-0.01188751	0.00684839
12	12	*Alchemilla glabra* Neygenf.	0.01743369	0.00710934
13	13	*Alchemilla glabra* Neygenf.	0.01677315	-0.03715024
14	14	*Alchemilla monticola* Opiz	-0.06770742	0.00617348
15	15	*Alchemilla monticola* Opiz	-0.00014166	0.01127139
16	16	*Alchemilla monticola* Opiz	-0.01724829	-0.01206434
17	17	*Alchemilla monticola* Opiz	-0.00481797	0.00312784
18	18	*Alchemilla monticola* Opiz	-0.00600686	0.00027882
19	19	*Alchemilla monticola* Opiz	-0.03062967	0.01345445
20	20	*Alchemilla monticola* Opiz	-0.00920985	0.00205842
21	21	*Alchemilla propinqua* H.Lindb.	0.02106635	-0.00274551
22	22	*Alchemilla propinqua* H.Lindb.	-0.01468918	-0.00762619
23	23	*Alchemilla propinqua* H.Lindb.	-0.01168780	0.00774227
24	24	*Alchemilla propinqua* H.Lindb.	-0.02327981	-0.01053057
25	25	*Alchemilla plicata* Buser	-0.01876323	-0.02345774
26	26	*Alchemilla glaucescens* Wallr.	-0.02366420	0.01113946
27	27	*Alchemilla glaucescens* Wallr.	-0.02465184	0.00184440
28	28	*Alchemilla glaucescens* Wallr.	0.00277494	-0.00060405
29	29	*Alchemilla glaucescens* Wallr.	-0.03445956	-0.00581799
30	30	*Alchemilla glaucescens* Wallr.	0.01019946	0.01084034
31	31	*Alchemilla glabra* Neygenf.	0.01222603	0.09631074
32	32	*Alchemilla glabra* Neygenf.	0.01324219	-0.01511260
33	33	*Alchemilla glabra* Neygenf.	0.01908715	-0.01760150
34	34	*Alchemilla gracilis* Walters	0.00477400	-0.01032694
35	35	*Alchemilla gracilis* Walters	0.03093561	-0.01330133
36	36	*Alchemilla glaucescens* Wallr.	-0.01297225	-0.00600778
37	43	*Alchemilla gorcensis* Pawl.	-0.01751138	-0.01983185
38	44	*Alchemilla gorcensis* Pawl.	0.03428628	0.02173536
39	45	*Alchemilla acutiloba* Opiz	0.00971599	0.01574187
40	46	*Alchemilla acutiloba* Opiz	0.06516383	0.03019118
41	47	*Alchemilla acutiloba* Opiz	0.02343732	0.04476507
42	48	*Alchemilla acutiloba* Opiz	0.01734339	0.00344030
43	49	*Alchemilla acutiloba* Opiz	0.00915234	-0.02261498
44	50	*Alchemilla gracilis* Walters	0.02692970	-0.02258159
45	51	*Alchemilla gracilis* Walters	0.03064598	-0.01086293
46	52	*Alchemilla gracilis* Walters	0.03078237	-0.00975069
47	53	*Alchemilla gracilis* Walters	0.03945348	-0.02535990
48	54	*Alchemilla crinita* Buser	0.00532345	-0.00500466
49	55	*Alchemilla crinita* Buser	-0.03202396	-0.01033535
50	56	*Alchemilla crinita* Buser	0.03505731	-0.00047809
51	57	*Alchemilla crinita* Buser	-0.02979231	-0.00623437
52	58	*Alchemilla crinita* Buser	0.01042656	-0.00010220
53	59	*Alchemilla walasii* Pawl.	0.00148435	0.02936532

54	60	*Alchemilla walasii* Pawl.	0.03573846	-0.01473609
55	61	*Alchemilla walasii* Pawl.	-0.01429147	-0.05775246
56	62	*Alchemilla xanthochlora* Rothm.	0.02138162	0.00639854
57	63	*Alchemilla xanthochlora* Rothm.	0.00350761	-0.01290245
58	64	*Ilchemilla subglobosa* C.G.Wester	-0.00559398	-0.01050934
59	65	*Alchemilla pseudoincisa* Pawl.	-0.00755467	0.01264393
60	66	*Alchemilla plicata* Buser	-0.00973089	-0.02381372
61	67	*Alchemilla plicata* Buser	0.01238753	0.00984538
62	68	*Alchemilla plicata* Buser	-0.00235054	-0.01304798
63	69	*Alchemilla obtusa* Buser	-0.01782837	0.01232767
64	70	*Alchemilla subcrenata* Buser	0.00474703	-0.02019726
65	71	*Alchemilla subcrenata* Buser	-0.01143696	0.01793745
66	72	*Alchemilla subcrenata* Buser	0.01159819	-0.01302571
67	73	*Alchemilla subcrenata* Buser	-0.03156002	0.02890625
68	74	*Alchemilla subcrenata* Buser	-0.00324471	-0.00495108
69	75	*Alchemilla subcrenata* Buser	-0.01633205	0.02550383
70	76	*Alchemilla glaucescens* Wallr.	-0.02131616	-0.00266890
71	77	*Alchemilla glaucescens* Wallr.	0.01124018	-0.01577350

B. Summary of effective principal components

PC	Eigenvalue	*Proportion of variance (%)*	Cumulative variance (%)
PC1	0.0005563154	32.9330	32.9330
PC2	0.0004135046	24.4788	57.4118
PC3	0.0002061026	12.2009	69.6128
PC4	0.0000933237	5.5246	75.1374
PC5	0.0000806364	4.7735	79.9109
PC6	0.0000723508	4.2831	84.1940
PC7	0.0000528363	3.1278	87.3218
PC8	0.0000474825	2.8109	90.1327
PC9	0.0000380900	2.2549	92.3876

Note: Sample ID corresponds to the specimen identifier used in Table S1. For specimens represented by more than one achene, normalized EFD coefficients were averaged at the specimen level prior to PCA. The specimen-level PC1 and PC2 scores correspond to the PCA morphospace shown in Figure 4A. SHAPE identified 9 effective principal components; PC1 and PC2 together explained 57.4118% of total contour

Table S3. Combined voucher-level dataset used in the statistical analyses, including EFD-derived principal component scores, achene-shape descriptors, SEM-derived micromorphological characters, and environmental variables.

Table S3. Combined voucher-level dataset used in the statistical analyses, including EFD-derived principal component scores, achene-shape descriptors, SEM-derived micromorphological characters, and environmental variables.

EFD = Elliptical Fourier Descriptors. Binary SEM characters are coded as 1 = present and 0 = absent; NA = unavailable or not scored. BIO1–BIO19 are WorldClim bioclimatic variables; the remaining environmental variables are soil variables.

Identification			EFD-derived PC scores		Achene-shape descriptors				SEM-derived micromorphological characters							
No.	Species	Sample	EFD-PC1	EFD-PC2	Circularity	Aspect ratio	Roundness	Solidity	Apex: acute-curved	Apex: acute	Apex: blunt-acuminate	Surface type 1	Surface type 2	Surface type 3	Sculpture: reticulate	Sculpture: colliculate
1	*A. monticola*	1	-0.01142702	-0.0020311	0.476555556	1.476111111	0.681777778	0.683666667	0	0	1	0	1	0	1	0
2	*A. glabricaulis*	2	0.01029835	-0.00292357	0.553666667	1.543166667	0.650083333	0.762083333	0	1	1	NA	NA	NA	NA	NA
3	*A. monticola*	3	-0.01622599	0.0167664	0.478714286	1.407428571	0.721857143	0.704142857	0	0	1	0	1	0	1	0
4	*A. monticola*	4	-0.00256721	0.00183267	0.449666667	1.433666667	0.703333333	0.777666667	0	0	1	0	1	0	1	0
5	*A. hirsuticaulis*	5	-0.01196134	0.001509	0.433636364	1.423272727	0.707545455	0.584090909	NA	NA	NA	NA	NA	NA	NA	NA
6	*A. oraciliis*	6	0.02606789	0.02426544	0.51275	1.74875	0.5765	0.7165	1	1	0	0	1	0	1	0
7	*A. oraciliis*	7	-0.00544452	0.00766808	0.545375	1.31425	0.763375	0.79125	0	0	1	0	1	0	1	0
8	*A. monticola*	8	0.03454953	-0.0096805	0.275	1.815	0.5515	0.651	0	0	1	0	1	0	1	0
9	*A. monticola*	9	-0.01126214	0.00119103	0.55	1.468	0.6875	0.7625	0	0	1	0	1	0	1	0
10	*A. monticola*	10	-0.00679881	0.00928293	0.544666667	1.393	0.718	0.735333333	0	0	1	0	1	0	1	0
11	*A. glaucescens*	11	-0.01188751	0.00684839	0.363	1.277	0.789	0.6895	0	1	0	0	1	0	1	0
12	*A. glabra*	12	0.01743369	0.00710934	0.411666667	1.589333333	0.63	0.698	1	0	0	0	1	0	1	0
13	*A. glabra*	13	0.01677315	-0.03715024	0.339333333	1.895	0.533	0.632	1	0	0	0	1	0	1	0
14	*A. monticola*	14	-0.06770742	0.00617348	0.392	1.350666667	0.748666667	0.662666667	0	0	1	0	1	0	1	0
15	*A. monticola*	15	-0.00014166	0.01127139	0.523666667	1.51	0.673333333	0.704	0	0	1	0	1	0	1	0
16	*A. monticola*	16	-0.01724829	-0.01206434	0.3664	1.5222	0.6636	0.6754	0	0	1	0	1	0	1	0
17	*A. monticola*	17	-0.00481797	0.00312784	0.64	1.314	0.7615	0.783	0	0	1	0	1	0	1	0
18	*A. monticola*	18	-0.00600686	0.00027882	0.686714286	1.378857143	0.726857143	0.863142857	0	0	1	0	1	0	1	0
19	*A. monticola*	19	-0.03062967	0.01345445	0.634333333	1.362	0.735333333	0.781666667	0	0	1	0	1	0	1	0
20	*A. monticola*	20	-0.00920985	0.00205842	0.572	1.362666667	0.741333333	0.707333333	0	0	1	0	1	0	1	0
21	*A. propinaua*	21	0.02106635	-0.00274551	0.50275	1.50925	0.6715	0.695	1	0	0	0	1	0	0	1
22	*A. propinaua*	22	-0.01468918	-0.00762619	0.681666667	1.50925	0.694666667	0.846	1	0	0	0	1	0	0	1
23	*A. propinaua*	23	-0.0116878	0.00774227	0.518666667	1.50925	0.735333333	0.637	1	0	0	0	1	0	0	1
24	*A. propinaua*	24	-0.02327981	-0.01053057	0.5	1.50925	0.738	0.654666667	1	0	0	0	1	0	0	1
25	*A. plicata*	25	-0.01876323	-0.02345774	0.424333333	1.50925	0.753333333	0.682333333	1	0	0	1	0	0	1	0
26	*A. glaucescens*	26	-0.0236642	0.01113946	0.139666667	1.50925	0.719333333	0.637	1	0	0	0	1	0	1	0
27	*A. glaucescens*	27	-0.02465184	0.0018444	0.115	1.50925	0.7365	0.621	0	1	0	0	1	0	1	0
28	*A. glaucescens*	28	0.00277494	-0.00806405	0.3	1.50925	0.8065	0.6475	1	0	0	0	1	0	1	0
29	*A. glaucescens*	29	-0.03445956	-0.00581799	0.536666667	1.50925	0.831666667	0.673	1	0	0	0	1	0	1	0
30	*A. glaucescens*	30	0.01019946	0.01084034	0.344	1.50925	0.755333333	0.680333333	0	1	0	0	1	0	1	0
31	*A. glabra*	31	0.01222603	0.09631074	0.415	1.50925	0.524	0.7945	0	1	0	0	1	0	1	0
32	*A. glabra*	32	0.01324219	-0.0151126	0.606	1.50925	0.697	0.816	0	1	0	0	1	0	1	0
33	*A. glabra*	33	0.01908715	-0.0176015	0.515	1.50925	0.64475	0.7215	0	1	0	0	1	0	1	0
34	*A. oraciliis*	34	0.004774	-0.01032694	0.518666667	1.50925	0.719666667	0.677666667	1	0	0	0	1	0	1	0
35	*A. oraciliis*	35	0.03093561	-0.01330133	0.211333333	1.50925	0.532	0.635333333	1	0	0	0	1	0	1	0
36	*A. glaucescens*	36	-0.01297225	-0.00600778	0.3576	1.50925	0.8274	0.729	0	1	0	0	1	0	1	0
37	*A. sorcensis*	43	-0.01751138	-0.01983185	0.425333333	1.50925	0.627333333	0.744333333	0	1	0	1	0	0	1	0
38	*A. sorcensis*	44	0.03428628	0.02173536	0.51375	1.50925	0.6125	0.7355	0	1	0	1	0	0	1	0
39	*A. acutiloba*	45	0.00971599	0.01574187	0.492833333	1.50925	0.723666667	0.650666667	0	1	0	1	0	0	1	0
40	*A. acutiloba*	46	0.06516383	0.03019118	0.414	1.50925	0.5825	0.5915	0	1	0	1	0	0	1	0
41	*A. acutiloba*	47	0.02343732	0.04476507	0.3072	1.50925	0.6054	0.6676	0	1	0	1	0	0	1	0
42	*A. acutiloba*	48	0.01734339	0.0034403	0.4976	1.50925	0.7144	0.6368	0	1	0	1	0	0	1	0
43	*A. acutiloba*	49	0.00915234	-0.02261498	0.25875	1.50925	0.6925	0.656	0	1	0	1	0	0	1	0
44	*A. oraciliis*	50	0.0269297	-0.02258159	0.3315	1.50925	0.6045	0.6285	1	0	0	0	1	0	1	0
45	*A. oraciliis*	51	0.03064598	-0.01086293	0.424333333	1.50925	0.661166667	0.673333333	1	0	0	0	1	0	1	0
46	*A. oraciliis*	52	0.03078237	-0.00975069	0.3674	1.50925	0.6032	0.6794	1	0	0	0	1	0	1	0
47	*A. oraciliis*	53	0.03945348	-0.0253599	0.421	1.50925	0.636	0.637	0	1	0	0	1	0	1	0
48	*A. crinita*	54	0.00532345	-0.00500466	0.5324	1.50925	0.6756	0.6814	1	0	0	0	1	0	1	0
49	*A. crinita*	55	-0.03202396	-0.01033535	0.4274	1.50925	0.819	0.6676	1	0	0	0	1	0	1	0
50	*A. crinita*	56	0.03505731	-0.00047809	0.3878	1.50925	0.6892	0.6236	1	0	0	0	1	0	1	0
51	*A. crinita*	57	-0.02979231	-0.00623437	0.4256	1.50925	0.7192	0.6598	1	0	0	0	1	0	1	0
52	*A. crinita*	58	0.01042656	-0.0001022	0.556833333	1.50925	0.716333333	0.7615	1	0	0	0	1	0	1	0
53	*A. walasii*	59	0.00148435	0.029365 32	0.508666667	1.50925	0.682	0.682666667	1	0	0	0	1	0	0	1
54	*A. walasii*	60	0.03573846	-0.01473609	0.4818	1.50925	0.628	0.6444	1	0	0	0	1	0	0	1
55	*A. walasii*	61	-0.01429147	-0.05775246	0.40525	1.50925	0.7285	0.63	1	0	0	0	1	0	0	1
56	*A. xanthochlora*	62	0.02138162	0.00639854	0.421833333	1.50925	0.710333333	0.816666667	0	1	0	0	1	0	0	1
57	*A. xanthochlora*	63	0.00350761	-0.01290245	0.53025	1.50925	0.7195	0.6795	0	1	0	0	1	0	0	1
58	*A. subobtosa*	64	-0.00559398	-0.01050934	0.3876	1.50925	0.7522	0.681	NA	NA	NA	0	0	1	1	0
59	*A. pseudoincisa*	65	-0.00755467	0.01264393	0.501666667	1.50925	0.654666667	0.669	1	0	0	NA	NA	NA	NA	NA
60	*A. plicata*	66	-0.00973089	-0.02581372	0.2034	1.50925	0.8198	0.645	1	0	0	1	0	0	1	0
61	*A. plicata*	67	0.01238753	0.00984538	0.5015	1.50925	0.746	0.66125	1	0	0	1	0	0	1	0
62	*A. plicata*	68	-0.00235054	-0.01304798	0.5225	1.50925	0.753	0.7245	1	0	0	1	0	0	1	0
63	*A. obtusa*	69	-0.01782837	0.01232767	0.5415	1.50925	0.699	0.74025	1	0	0	NA	NA	NA	NA	NA
64	*A. subcrenata*	70	0.00474703	-0.02019726	0.4108	1.50925	0.7852	0.6474	1	0	0	0	1	0	1	0
65	*A. subcrenata*	71	-0.01143696	0.01793745	0.419	1.50925	0.6925	0.6875	1	0	0	0	1	0	1	0
66	*A. subcrenata*	72	0.01159819	-0.01302571	0.588333333	1.50925	0.701	0.796666667	1	0	0	0	1	0	1	0
67	*A. subcrenata*	73	-0.03156002	0.02890625	0.5545	1.50925	0.699	0.7475	1	0	0	0	1	0	1	0
68	*A. subcrenata*	74	-0.00324471	-0.00495108	0.5264	1.50925	0.6956	0.7	1	0	0	0	1	0	1	0
69	*A. subcrenata*	75	-0.01633205	0.02550383	0.501666667	1.50925	0.720333333	0.672666667	1	0	0	0	1	0	1	0
70	*A. glaucescens*	76	-0.02131616	-0.0026689	0.5566	1.50925	0.7354	0.7192	0	1	0	0	1	0	1	0
71	*A. glaucescens*	77	0.01124018	-0.0157735	0.48875	1.50925	0.67125	0.6485	1	0	0	0	1	0	1	0

									Climatic variables						
Epidermal cell shape: polygonal	Epidermal cell shape: polygonal-	Epidermal cell shape: elongated	Anticlinal wall pattern: straight	Anticlinal wall pattern: undulate	Periclinal wall relief: raised	Periclinal wall relief: depressed	Anticlinal wall relief: depressed	Anticlinal wall relief: raised	BIO1	BIO2	BIO3	BIO4	BIO5	BIO6	BIO7
0	1	0	1	0	1	0	1	0	7.972158909	6.744318008	27.20480347	680.8908081	21.5727272	-3.218181849	24.79090881
NA	NA	NA	NA	NA	NA	NA	NA	NA	7.230666637	6.867333412	27.95235062	672.7019043	20.78000069	-3.788000107	24.56800079
0	1	0	1	0	1	0	1	0	7.005000114	6.946666718	27.74671173	685.1134644	20.74399948	-4.292000294	25.0359993
0	1	0	1	0	1	0	1	0	8.040333271	8.661999702	32.58840942	674.1891479	19.09600067	-7.484000206	26.58000183
NA	NA	NA	NA	NA	NA	NA	NA	NA	7.149166584	6.948333263	27.99489784	678.1455078	20.79599953	-4.024000168	24.81999969
0	1	0	0	1	1	0	1	0	7.230666637	6.867333412	27.95235062	672.7019043	20.78000069	-3.788000107	24.56800079
0	1	0	1	0	1	0	1	0	7.252500057	6.948333263	27.62537193	688.6229248	21.01600075	-4.13599968	25.15200043
0	1	0	1	0	1	0	1	0	6.83983326	6.914333344	27.49019432	691.8132935	20.58799934	-4.56400013	25.15200043
0	1	0	1	0	1	0	1	0	7.252500057	6.948333263	27.62537193	688.6229248	21.01600075	-4.13599968	25.15200043
0	1	0	1	0	1	0	1	0	7.799166679	6.746333122	28.45593452	647.9829712	21.06800079	-2.639999866	23.70800018
0	1	0	1	0	1	0	1	0	5.946833134	7.570333004	29.69689751	683.4042969	19.8239994	-5.667999744	25.49199867
0	0	1	1	0	1	0	1	0	7.468666553	6.913333416	28.1166954	673.8935547	21.05200005	-3.536000013	24.58799934
0	0	1	1	0	1	0	1	0	6.969666958	6.922667027	27.79740906	685.9093628	20.70000076	-4.203999996	24.90400124
0	1	0	1	0	1	0	1	0	6.946833134	6.90233326	27.55202484	687.505127	20.66399956	-4.388000011	25.05200005
0	1	0	1	0	1	0	1	0	6.894833088	7.058333397	27.74065971	698.4094849	20.76799965	-4.675999641	25.04400024
0	1	0	1	0	1	0	1	0	7.168166637	6.958333492	28.02163887	674.6513062	20.7840004	-4.047999859	24.83200073
0	1	0	1	0	1	0	1	0	7.164666653	7.484666824	28.66370392	711.5834351	21.54000092	-4.572000027	26.11200142
0	1	0	1	0	1	0	1	0	7.279500008	7.388333321	28.24286461	714.3400879	21.56800079	-4.592000008	26.15999985
0	1	0	1	0	1	0	1	0	7.137499809	6.93900013	28.1615257	668.7944336	20.66799927	-3.972000122	24.63999939
0	1	0	1	0	1	0	1	0	6.927999973	6.941999912	27.84820366	685.0593262	20.66399956	-4.263999939	24.9279995
0	1	0	1	0	1	0	1	0	7.386833191	7.481666565	27.50612831	752.3409424	21.95999908	-5.239999771	27.19999886
0	0	1	1	0	1	0	1	0	7.468500137	6.852333546	27.32626152	688.1422729	21.20800018	-3.868000031	25.07600021
0	0	1	1	0	1	0	1	0	5.628000259	7.409333229	29.13848305	685.3839722	19.4279995	-6	25.4279995
0	0	1	1	0	1	0	1	0	7.352833271	7.029000282	27.82219887	693.4500122	21.25600052	-4.007999897	25.26399994
0	0	1	1	0	1	0	1	0	6.973499775	6.941666603	27.78000069	682.5333252	20.63999939	-4.34800005	24.98799896
0	1	0	1	0	1	0	1	0	7.083499908	9.189666748	31.94405746	734.605896	22.01600075	-6.751999855	28.76800156
0	1	0	1	0	1	0	1	0	5.892333031	8.710666656	31.22550392	723.4374779	20.48399925	-7.412000179	27.89599991
0	1	0	1	0	1	0	1	0	6.572333336	7.815999985	27.88241959	764.9630127	21.57600021	-6.455999851	28.03199959
0	1	0	1	0	1	0	1	0	7.001333237	7.147333145	27.88441467	700.6732788	21.0720005	-4.559999943	25.63199997
0	1	0	1	0	1	0	1	0	7.657666683	6.71600008	27.71541786	663.9628296	21.05200005	-3.180000067	24.23200035
0	0	1	1	0	1	0	1	0	7.021999836	6.746666908	27.39874458	678.7919312	20.55999947	-4.06400013	24.62400055
0	0	1	1	0	1	0	1	0	8.469333649	7.451999664	28.29157257	720.2550049	23.0359993	-3.303999901	26.34000015
0	0	1	1	0	1	0	1	0	7.021999836	6.746666908	27.39874458	678.7919312	20.55999947	-4.06400013	24.62400055
0	0	1	1	0	1	0	1	0	7.165166378	7.22699976	27.5209446	720.258606	21.29599953	-4.964000225	26.26000023
0	1	0	0	1	1	0	1	0	7.252500057	6.948333263	27.62537193	688.6229248	21.01600075	-4.13599968	25.15200043
0	1	0	1	0	1	0	1	0	5.892333031	8.710666656	31.22550392	723.4374779	20.48399925	-7.412000179	27.89599991
1	0	0	1	0	1	0	1	0	4.497499943	8.200333595	31.7006855	667.9691772	18.26799965	-7.599999905	25.86800003
1	0	0	1	0	1	0	1	0	8.030500412	7.847000122	29.01567841	727.2056274	22.62000084	-4.424000263	27.04400063
1	0	0	1	0	1	0	1	0	8.16166687	8.151332855	29.51670456	735.5108032	23.12800026	-4.487999916	27.61600113
1	0	0	1	0	1	0	1	0	8.522666931	8.714666367	31.52462196	718.4648438	23.41600037	-4.228000164	27.64400101
1	0	0	1	0	1	0	1	0	7.961499691	7.925666332	28.87941551	743.727417	22.43199921	-5.012000084	27.44400024
1	0	0	1	0	1	0	1	0	7.896333218	8.977333069	30.39043045	770.7344971	23.54800034	-5.992000103	29.54000092
1	0	0	1	0	1	0	1	0	8.259666443	8.674666405	29.14874458	792.2000732	24.15999985	-5.599999905	29.76000023
0	1	0	0	1	1	0	1	0	7.967833042	8.198332787	28.14975166	784.7910767	23.43199921	-5.691999912	29.12399864
0	1	0	0	1	1	0	1	0	8.078166962	8.190333366	27.93047905	789.5151367	23.70800018	-5.615999699	29.3239994
0	1	0	0	1	1	0	1	0	7.886000156	8.526666641	28.93534279	785.6781006	23.55200005	-5.915999889	29.46800041
0	1	0	0	1	1	0	1	0	7.886000156	8.526666641	28.93534279	785.6781006	23.55200005	-5.915999889	29.46800041
1	0	0	1	0	1	0	1	0	7.904666424	8.642000198	29.06632614	791.3991699	23.8599987	-5.872000217	29.73199844
1	0	0	0	1	1	0	1	0	7.958166599	7.714333057	28.8063221	723.0734253	22.07600021	-4.703999996	26.78000069
1	0	0	0	1	1	0	1	0	7.502666473	8.898666382	31.81276512	721.0551758	22.43199921	-5.539999962	27.97200012
1	0	0	0	1	1	0	1	0	8.17650032	8.255000114	29.67289734	750.5429688	22.89999962	-4.920000076	27.81999969
1	0	0	0	1	1	0	1	0	7.846666813	8.378000259	28.45788002	787.5507202	23.60400009	-5.835999966	29.44000053
0	1	0	0	1	1	0	1	0	4.083666801	8.916666985	33.29598999	679.4381104	18.33600044	-8.444000244	26.78000069
0	1	0	0	1	1	0	1	0	3.50816679	8.505666733	32.31636429	674.9282227	17.52000046	-8.800000191	26.31999969
0	1	0	0	1	1	0	1	0	6.407833099	9.449666977	32.7976799	732.1553955	21.6439991	-7.167999744	28.81199837
0	1	0	0	1	1	0	1	0	4.880333424	9.639333725	34.66887283	692.1377563	19.6119995	-8.192000389	27.80400085
0	1	0	0	1	1	0	1	0	7.486999989	8.702666283	30.41614151	752.2001343	22.55999947	-6.052000046	28.61199951
1	0	0	0	1	0	1	0	1	5.470499992	7.361000061	29.51010323	674.0254517	19.2159996	-5.728000164	24.94400024
NA	NA	NA	NA	NA	NA	NA	NA	NA	1.37683332	7.427666664	29.79648209	663.7675781	14.70399952	-10.22399998	24.9279995
0	0	1	1	0	1	0	1	0	6.764666557	8.414000511	28.90614319	800.2913818	22.61600113	-6.492000103	29.10800171
0	0	1	1	0	1	0	1	0	8.326000214	8.935333252	31.10755348	749.7875366	23.50799942	-5.21600008	28.72399902
0	0	1	1	0	1	0	1	0	8.055666924	8.840666771	29.5872364	788.3010864	24.02000046	-5.860000134	29.88000107
NA	NA	NA	NA	NA	NA	NA	NA	NA	4.880333424	9.639333725	34.66887283	692.1377563	19.61199951	-8.192000389	27.80400085
0	1	0	0	1	1	0	1	0	6.883833408	8.197666168	28.37348175	798.303833	22.54400063	-6.34800005	28.8920002
0	1	0	0	1	1	0	1	0	8.053999901	8.308000565	29.17954636	766.3085327	23.4319921	-5.039999962	28.47200012
0	1	0	0	1	1	0	1	0	7.502666473	8.898666382	31.81276512	721.0551758	22.43199921	-5.539999962	27.97200012
0	1	0	0	1	1	0	1	0	7.994666576	8.614666939	29.00170517	783.3925781	23.83200073	-5.872000217	29.70400047
0	1	0	0	1	1	0	1	0	4.046000004	8.817333221	33.15784073	677.4659424	18.23200035	-8.359999657	26.59199905
0	1	0	0	1	1	0	1	0	7.934000015	8.320666313	28.41369629	785.5102539	23.52400017	-5.760000229	29.2840004
0	1	0	1	0	1	0	1	0	7.28233374	6.948666573	27.84813499	687.0443726	21.08399963	-3.868000031	24.95199966
0	1	0	1	0	1	0	1	0	7.414000034	6.968666553	28.48073578	668.6417236	20.97200012	-3.496000051	24.46800041

Soil variables																			
BIO8	BIO9	BIO10	BIO11	BIO12	BIO13	BIO14	BIO15	BIO16	BIO17	BIO18	BIO19	AWC	Bulk density	CaCO3	CEC	Clay	C:N ratio	Coarse fragments	K
15.9333333	2.825000008	16.46287918	-0.187878788	632.	75.	30.	29.60471725	213.	97.	211.	120.	0.068623471	1.506146008	8.682459831	13.91260779	11.09284878	15.71541119	14.69211278	116.1663666
15.11866665	2.092000008	15.59066677	-0.791333318	670.	78.	33.	27.89975929	225.	106.	214.	132.	0.066046089	1.426676989	5.349156857	10.73699951	5.834161282	13.09248829	12.07586479	134.5396729
14.95266724	1.84799993	15.48999977	-1.216666698	678.	80.	34.	26.9577961	225.	110.	220.	134.	0.071315058	1.240738511	19.062006	14.35005951	9.982157707	10.83958817	9.667337418	110.1615753
13.32733345	-3.118666649	13.32733345	-3.118666649	1206.	164.	62.	32.31357956	444.	204.	444.	204.	0.101337738	1.081821203	52.03410721	16.26777458	14.00146103	13.21236229	31.68407249	197.5415039
15.06866646	2.012000084	15.55999947	-0.963999987	668.	78.	33.	27.53818512	222.	106.	214.	132.	0.074934795	1.361330271	0.320577621	11.74305344	4.37301445	12.35395336	9.16809082	108.1707382
15.11866665	2.092000008	15.59066677	-0.791333318	670.	78.	33.	27.89975929	225.	106.	214.	132.	0.066046089	1.426676989	5.349156857	10.73699951	5.834161282	13.09248829	12.07586479	134.5396729
15.76933384	2.131999969	15.76933384	-1.075999975	658.	80.	32.	28.72617149	221.	104.	221.	126.	0.069457307	1.506566525	13.84401703	14.53316307	11.04173946	15.87962532	14.71766758	73.41191101
15.37133312	1.718000054	15.37133312	-1.541333318	681.	82.	34.	27.80506516	227.	110.	227.	132.	0.078203514	1.465953946	2.431813478	10.4593668	13.54446411	12.21870422	10.99711037	78.25313568
15.76933384	2.131999969	15.76933384	-1.075999975	658.	80.	32.	28.72617149	221.	104.	221.	126.	0.071904704	1.497414947	7.776178837	14.61549568	8.708500862	15.90225029	8.434547424	92.81690216
15.60533333	2.55466758	15.92666626	0.25333336	612.	69.	31.	27.72288513	203.	97.	189.	125.	0.064144395	1.388288617	7.204767704	13.10839653	13.79945087	13.90509033	5.637264252	96.35791779
14.2373333	-1.531333327	14.2373333	-2.484666586	632.	94.	28.	45.32578607	266.	91.	266.	94.	0.08372248	1.44314456	0.	15.16771889	14.91257286	11.90725708	21.10919952	178.1588593
15.37466717	2.304666519	15.85933304	-0.566000044	662.	77.	33.	27.63252831	221.	106.	211.	130.	0.072266139	1.476961017	36.26335907	11.73126221	9.545117378	10.3950386	8.602841377	107.3565521
14.9386673	1.766666532	15.47533417	-1.257333398	688.	80.	34.	27.19707489	228.	110.	223.	136.	0.077372916	1.270546317	0.	10.68252087	10.32758808	11.86971474	11.99510193	117.7585373
14.90799999	1.785333276	15.45933342	-1.310000062	681.	79.	34.	26.8778582	225.	110.	221.	134.	0.070341878	1.301414013	6.999484062	12.70881748	8.615221977	13.10269451	11.14795399	84.53812408
15.49399948	1.779333353	15.49399948	-1.595999956	676.	81.	33.	27.66144562	225.	109.	225.	130.	0.069460921	1.212360501	0.634216011	16.27676392	8.743183136	12.13631058	17.73936081	79.77329254
15.04466724	2.077333212	15.5253334	-0.905333281	667.	77.	33.	27.38572231	221.	106.	212.	132.	0.062086634	1.346553802	3.055244684	16.97535896	5.992729664	13.08793354	10.18554306	73.08194733
15.90200043	2.018000126	15.90200043	-1.535333395	648.	80.	31.	28.81063271	220.	103.	220.	122.	0.081378594	1.200547099	27.5188961	16.31535339	14.07071114	10.70323277	14.23377419	114.7614365
16.05533409	2.126666546	16.05533409	-1.428666711	632.	79.	30.	28.67313004	214.	101.	214.	119.	0.059846211	1.324960232	4.96087122	10.0491991	7.784671307	12.65905666	9.0084095	100.8045959
14.96999931	2.061333418	15.43133259	-0.849333346	676.	79.	33.	27.42044258	224.	107.	214.	134.	0.061079945	1.510638952	0.	4.010677814	6.055986404	9.958291054	7.665732384	109.0784149
14.88333321	1.744666576	15.42533302	-1.289999962	687.	80.	34.	27.15511703	228.	110.	223.	136.	0.072236858	1.170310378	0.	10.67804146	9.945879936	11.72515678	10.2913084	98.2213925
16.51533318	2.268666744	16.51533318	-1.938666701	688.	81.	31.	27.79944038	231.	110.	231.	134.	0.059692934	1.359261632	17.71454811	11.71706963	6.998916626	9.939119339	5.425553322	82.26778412
15.45199966	2.330666542	16.01533318	-0.819999993	664.	78.	33.	28.2743206	221.	105.	219.	129.	0.076818094	1.284573674	3.566293716	18.15048218	10.59200287	11.87978554	9.205555916	75.54224396
13.95733356	-1.869333267	13.95733356	-2.842000008	655.	94.	30.	42.54308701	270.	97.	270.	103.	0.079731271	1.482516885	22.39754868	26.90446091	7.930981159	17.16841125	20.96641159	202.0860291
15.38466644	2.177333355	15.95466709	-1.00333333	670.	79.	33.	27.97028542	223.	107.	221.	130.	0.068453655	1.262220144	5.366326732	13.26424503	9.588430405	10.66461468	8.427985191	79.96987915
14.89866696	1.850000024	15.42066669	-1.223333359	679.	80.	34.	27.23226738	225.	109.	220.	134.	0.068374899	1.35101223	9.112381935	8.130813599	10.52959728	11.18810463	11.65592575	108.3846817
14.52933311	2.488666773	15.92000008	-2.181999922	990.	146.	44.	40.28233337	388.	155.	383.	201.	0.102916621	1.205567956	25.45563698	31.50009346	22.70114136	13.72421932	11.16408157	109.1887817
14.61866665	1.183333278	14.61866665	-3.164666653	1002.	147.	45.	39.63894653	392.	164.	392.	181.	0.10077361	1.209509969	53.3683815	24.11156082	22.09955978	10.33834553	14.79228973	106.5394592
15.86933327	-2.017333269	15.86933327	-2.884666681	595.	81.	29.	32.64212418	218.	97.	218.	104.	0.057358954	1.255104065	0.	6.486266613	2.864353657	21.7613945	5.395242214	64.41680908
15.04933357	1.840666652	15.65333366	-1.464666605	667.	79.	33.	27.44586563	221.	107.	219.	130.	0.063470289	1.17471242	0.	10.54375648	10.44613934	16.31221581	6.552326679	138.5503998
15.50266647	2.500666618	15.95400047	-0.226000011	650.	76.	32.	27.74855042	216.	103.	208.	128.	0.074302077	1.386029243	0.	13.48291779	9.493564606	16.88095665	12.11494064	118.9407654
14.94666686	1.843333364	15.44866657	-1.095333338	690.	79.	35.	26.67682457	227.	112.	221.	137.	0.066379152	1.215057611	0.	7.041725159	8.27052021	12.62230587	9.770273209	53.42315292
17.40866661	0.734000027	17.40866661	-0.280666649	590.	74.	29.	27.19681549	204.	104.	204.	117.	0.05667049	1.320958	9.931444	5.707465	2.891905	22.40992	5.909067	32.01215
14.94666686	1.843333364	15.44866657	-1.095333338	690.	79.	35.	26.67682457	227.	112.	221.	137.	0.06535323	1.286380887	0.	12.67357731	6.322797775	11.3426466	10.55606842	104.1783142
15.95733261	2.134666681	15.95733261	-1.696666676	624.	75.	29.	26.19363213	206.	104.	206.	121.	0.069321312	1.121530652	8.210887909	8.77637291	9.988697052	10.11839867	10.13587761	98.93280438
15.76933384	2.131999969	15.76933384	-1.075999975	658.	80.	32.	28.72617149	221.	104.	221.	126.	0.069457307	1.506566525	13.84401703	14.53316307	11.04173946	15.87962532	14.71766758	73.41191101
14.61866665	1.183333278	14.61866665	-3.164666653	1002.	147.	45.	39.63894653	392.	164.	392.	181.	0.10077361	1.209509969	53.3683815	24.11156082	22.09955978	10.33834553	14.79228973	106.5394592
12.71866703	-2.850666761	12.71866703	-3.539999962	1275.	188.	59.	42.33425903	517.	190.	517.	196.	0.082617626	1.139058113	14.86878395	17.19232559	11.61287022	13.65716743	18.80570712	124.9127655
16.89866638	0.123333216	16.89866638	-0.945333421	621.	86.	29.	36.20555496	237.	96.	237.	105.	0.054699551	1.296590805	1.138709545	6.267533302	3.968822241	14.94440365	5.633099556	97.4910965
17.12999916	0.158000097	17.12999916	-0.925999999	605.	84.	28.	36.54085922	231.	93.	231.	102.	0.061040003	1.412981868	9.562127113	9.299623489	5.895406266	12.72729198	5.711982147	103.6629791
17.25933266	0.764666736	17.25933266	-0.441333324	628.	94.	27.	41.70717621	250.	88.	250.	91.	0.071371518	1.469371319	16.51614761	11.62734127	15.89839172	11.8454752	6.58441782	164.3892822
16.98266602	-0.127333328	16.98266602	-1.276000023	617.	83.	26.	39.52277374	241.	90.	241.	98.	0.060981758	1.189331889	2.7628901	6.087610245	4.973439693	14.50769806	7.119736195	84.13972473
17.15666771	-0.520666718	17.15666771	-1.843333346	591.	82.	26.	37.75973129	233.	90.	233.	96.	0.069977634	1.124924541	6.072521687	8.470172882	10.95880032	11.59901047	6.176679611	123.6018982
17.68000031	-0.3513335	17.68000031	-1.925333381	516.	73.	21.	37.5951598	200.	77.	200.	84.	0.047272205	1.535594823	5.217080593	2.301529646	4.310465228	8.760745049	6.586253643	121.6986542
17.30266571	-0.551333308	17.30266571	-2.070666552	550.	77.	23.	36.99263	213.	83.	213.	91.	0.055049405	1.441783667	0.	7.093724728	5.129894257	14.08367634	9.18598175	96.30467224
17.49866676	-0.44600001	17.49866676	-2.001333237	554.	78.	23.	37.58893585	216.	84.	216.	91.	0.056379378	1.453684688	0.	4.234019756	5.582363129	13.33473778	6.930831909	112.57444
17.23333359	-0.637333333	17.23333359	-2.147333384	548.	77.	23.	38.06302643	215.	81.	215.	89.	0.054820158	1.368173957	0.	6.480648518	5.180335522	11.23200893	4.868462086	75.31490326
17.23333359	-0.637333333	17.23333359	-2.147333384	548.	77.	23.	38.06302643	215.	81.	215.	89.	0.054820158	1.368173957	0.	6.480648518	5.180335522	11.23200893	4.868462086	75.31490326
17.39466667	-0.744000077	17.39466667	-2.134000063	542.	76.	23.	38.03485107	213.	80.	213.	88.	0.055302426	1.206439137	0.	5.023864109	6.112242222	10.0892531	6.164779592	96.64767456
16.74133301	0.098666586	16.74133301	-1.039999962	648.	89.	28.	38.84121704	251.	94.	251.	103.	0.059175488	1.261762619	4.799555302	5.089348316	5.960385799	19.61375427	10.76574516	69.40145111
16.25	-0.281333327	16.25	-1.531333327	879.	115.	44.	35.74448395	333.	138.	333.	146.	0.098121829	1.372229338	NA	NA	24.8895092	NA	16.94860268	NA
17.29800034	0.046666611	17.29800034	-1.128666639	596.	80.	25.	39.05278015	230.	87.	230.	95.	0.070504062	1.176938057	14.31620979	7.01928997	11.23127651	12.07017517	8.35859108	150.3897705
17.2626667	-0.763333321	17.2626667	-2.174000025	545.	77.	23.	37.70290756	214.	82.	214.	89.	0.060907133	1.500756383	0.	5.523204041	8.351955414	10.10673332	6.631824017	104.4535141
12.42066669	-3.384000063	12.42066669	-4.14533329	1174.	172.	49.	45.15008926	483.	161.	483.	164.	0.100314371	1.071359787	22.28440666	22.23719388	13.40703678	24.45866013	83.38614655
11.79933357	-3.945333242	11.79933357	-4.637333393	1207.	172.	53.	42.83655548	487.	171.	487.	177.	0.087097101	1.099162221	0.	16.4629364	15.73557281	11.45628738	19.11434174	13.94772339
15.21066666	-1.539999962	15.21066666	-2.840666771	984.	124.	54.	31.21135139	359.	170.	359.	181.	0.098439164	1.053002238	16.92233086	9.947806358	18.48315811	13.14907742	14.81801414	133.4049377
13.32800007	-2.718000174	13.32800007	-3.590000153	1135.	171.	45.	47.38052368	476.	151.	476.	152.	0.091967769	1.06628859	38.11813736	22.05238914	17.56445313	13.00566959	20.45378494	90.51452637
16.48333359	-0.725333333	16.48333359	-2.089999914	739.	104.	33.	39.62562943	285.	106.	285.	115.	0.082688637	1.303307414	7.875574112	16.41897202	16.45525932	10.40775653	7.888051033	149.2948608
13.72333336	-1.834666729	13.72333336	-2.707999945	692.	102.	31.	44.04516983	289.	100.	289.	108.	0.088661708	1.465501308	24.87670517	24.88497734	10.40874004	15.21997166	25.09246826	105.4684525
9.564666748	-6.021333218	9.564666748	-6.481333256	1390.	182.	71.	34.92786026	522.	223.	522.	234.	0.08252304	1.133749962	48.72147751	16.19839668	14.52363205	13.19565868	40.00315475	183.927536
16.49733353	-2.137333393	16.49733353	-3.113333464	565.	82.	24.	36.15758896	215.	86.	215.	94.	0.057643004	1.198310137	0.	11.07861805	4.347165585	13.95343113	7.962181091	98.64537811
17.42266655	0.259333342	17.42266655	-1.057999969	680.	91.	30.	39.2545712	265.	100.	265.	106.	0.061967961	1.492267728	NA	NA	9.667378426	NA	5.667703629	NA
17.47766769	-0.526666727	17.47766769	-1.958666682	541.	77.	22.	39.71673965	216.	78.	216.	85.	0.072290346	1.410547137	6.462292194	7.440779209	10.28141689	11.72203732	5.338579178	68.54090881
13.32800007	-2.718000174	13.32800007	-3.590000153	1135.	171.	45.	47.38052368	476.	151.	476.	152.	0.094652191	1.059927821	18.49185181	20.28421866	16.41215897	12.86978531	15.96480274	111.4704971
16.58533287	-2.019999981	16.58533287	-2.99666667	555.	79.	23.	36.29013824	212.	84.	212.	92.	0.057316307	1.274317265	0.	6.256400108	3.59151721	19.74360847	4.483887672	71.95280457
17.44333267	-0.352666676	17.44333267	-1.395333409	465.	70.	21.	40.9336853	185.	65.	185.	74.	0.051968679	1.203243375	0.925157487	10.53574181	3.448803425	12.8487339	3.918786764	185.92453
16.25	-0.281333327	16.25	-1.531333327	879.	115.	44.	35.74448395	333.	138.	333.	146.	0.098121829	1.372229338	NA	NA	24.8895092	NA	16.94860268	NA
17.33666611	-0.539333403	17.33666611	-1.968666792	545.	77.	23.	39.77247238	218.	79.	218.	86.	0.057919428	1.470069647	0.433396697	7.661952496	6.560452461	10.2327013	6.366330624	78.55586243
12.35933304	-3.414000034	12.35933304	-4.13599968	1183.	172.	51.	44.20786667	483.	166.	483.	170.	0.100227483	1.031871915	11.26804447	13.36334419	18.27528763	12.05208778	22.31853676	74.91706848
17.28733253	-0.634000003	17.28733253	-2.094666719	537.	76.	22.	38.33926392	211.	79.	211.	86.	0.058432009	1.192480803	0.	6.179380417	7.233522475	9.972558975	7.438347816	101.572319
15.27400017	2.083333492	15.81733222	-0.961333334	675.	79.	34.	27.70963669	225.	108.	221.	132.	0.069421716	1.196422577	0.	15.0695076	7.250330925	14.50570011	8.001355171	113.3555298
15.28600025	2.275333405	15.73866653	-0.549333334	662.	77.	33.	26.9995575	220.	107.	209.	131.	0.070734337	1.491498113	5.655418396	14.8026619	8.560290337	12.90452385	7.52564621	100.6138

N	P	pH (CaCl2)	pH (H2O)	pH H2O/CaCl2 ratio	Sand	Silt
1.464544058	25.79177475	4.453029156	5.281670094	0.828640938	67.05609894	21.85105133
1.502923489	32.61575699	5.100708961	5.775886059	0.675177097	78.73930359	15.42653656
1.79839766	38.78845215	5.696883678	6.380205154	0.683321476	64.76981354	25.24803162
2.56791997	26.38364983	5.688989162	6.284647942	0.595658779	51.84206772	34.15647125
1.550332546	32.35718536	4.652646065	5.613938808	0.961292744	84.82118225	10.80580139
1.502923489	32.61575699	5.100708961	5.775886059	0.675177097	78.73930359	15.42653656
1.388288498	21.87293434	4.432924271	4.834952831	0.402028561	60.90400314	28.05426025
2.191536427	23.06537628	4.630020142	5.648248672	1.018228531	53.8777504	32.57778931
1.707049012	19.28422928	3.969743252	4.944086552	0.9743433	61.75133896	29.54016113
2.205694675	34.97954941	5.110856056	5.320245743	0.209389687	67.19238281	19.00816345
2.385016918	33.66347885	5.7876091	6.161113262	0.373504162	44.99863654	40.0927887
1.323737979	31.917696	5.76981163	6.379277706	0.609466076	61.5545311	28.90035248
1.671921015	38.38489151	5.441547394	6.057618141	0.616070747	70.65046692	19.02194214
1.54642725	33.29260635	5.08207798	5.465334415	0.383256435	70.3664856	21.01829529
1.827944404	37.98104477	4.787302494	5.332371235	0.545068741	69.04684448	22.2099762
1.605118632	38.25970459	4.593174458	5.305793762	0.712619305	76.05325317	17.95401764
1.612079024	38.1210022	5.994047165	6.561034203	0.566987038	61.38647079	24.54281616
1.084418178	33.09205627	5.467529297	5.929853916	0.462324619	72.54154968	19.67378235
1.054274201	47.23921204	5.484247308	5.999493122	0.515245914	74.31291199	19.63110352
1.629872918	35.58481979	5.080592155	5.734730244	0.654138088	56.07833099	33.97579193
1.155346274	33.6160202	5.647236347	6.198611259	0.551374912	73.21688843	19.78419495
1.693914175	26.6851368	4.600482464	5.433306217	0.832823753	55.98222351	33.42577362
2.998624086	29.13369751	4.838729858	5.495223999	0.656494141	67.22725677	24.84175873
1.549313426	42.00910568	5.090817928	6.103717804	1.012899876	69.81739044	20.59417725
1.374776602	36.97442245	5.400091171	5.958120346	0.558029175	67.5433197	21.92708588
2.666868448	10.37471867	5.348182201	5.690046787	0.341864586	26.88130188	50.41755676
2.722145319	11.16098213	5.885478497	6.222121239	0.336642742	33.58509827	44.31534195
1.112752557	21.72538757	3.814585924	4.728451729	0.913865805	88.39530182	8.740341187
1.427562952	35.60325623	5.235052109	5.644750595	0.409698486	65.6242728	23.92943573
1.804953456	22.02543259	4.264979362	4.716588497	0.451609135	65.9984436	24.50799561
1.214750648	39.90529251	5.122024059	5.419708729	0.297684669	73.65762329	18.07185364
1.31797	26.32781	3.753361	4.41708	0.6637197	87.3769	9.731194
1.54260362	44.99877548	5.253480911	6.06757021	0.814089298	72.96051025	20.71669006
1.488125205	41.89235306	5.305161953	5.756585121	0.451423168	69.82649231	20.18481445
1.388288498	21.87293434	4.432924271	4.834952831	0.402028561	60.90400314	28.05426025
2.722145319	11.16098213	5.885478497	6.222121239	0.336642742	33.58509827	44.31534195
2.822010756	18.62798309	4.830308914	5.840269566	1.009960651	66.77742767	21.60970306
1.326414824	39.99721146	4.469888687	5.574977875	1.105089188	80.21897888	15.81220245
1.77189219	47.83378983	5.12142813	5.629340649	0.507912636	70.12646484	23.97812653
1.665668368	28.99352646	4.669518948	5.232642174	0.563123226	21.79399109	62.30761719
1.146166921	34.39483643	4.575149059	5.404776573	0.829627514	82.29112244	12.73543549
2.193891048	32.90510178	4.79585743	5.300476074	0.504618645	67.80253601	21.23866272
1.000743389	44.86940765	5.23054409	5.610686779	0.380142689	79.03761292	16.65192413
1.212631106	39.83129501	4.931613445	5.42610836	0.494494915	73.74544525	21.12466431
1.195353031	40.97893524	4.363760471	5.124747753	0.760987282	75.36486816	19.05276489
1.177529693	39.64179993	4.555590153	5.199455261	0.643865108	79.19685364	15.62281036
1.177529693	39.64179993	4.555590153	5.199455261	0.643865108	79.19685364	15.62281036
1.127214789	38.7328949	4.940763474	5.693778515	0.753015041	73.93873596	19.94902039
1.067776918	25.08711815	3.959485531	4.788170338	0.828684807	79.54943848	14.49017334
NA	NA	NA	NA	NA	17.25267029	57.8578186
1.406613708	35.53172684	5.123093128	5.707010269	0.583917141	65.12915039	23.63957214
1.211423516	40.31837845	4.622202873	5.610734494	0.988532066	59.2098732	32.43817139
3.975325677	10.80749893	4.852596283	5.25363636	0.401040077	37.5045014	43.85594177
2.465745926	18.62167168	4.62897253	5.435028553	0.806056023	49.65779495	34.60662842
2.039747238	12.08754063	5.07569313	5.247185707	0.171492577	33.66363525	47.85320663
2.953354359	18.90590477	5.363935471	5.78135252	0.417417049	47.21617889	35.21936798
1.967677832	13.90872383	5.647995472	5.894892693	0.246897221	14.71063995	68.83409882
2.899295092	21.61028862	4.919355869	5.344555855	0.425199986	54.2436826	35.34757996
3.460098743	27.81399536	5.691267014	6.28520298	0.593935966	49.79336548	35.68299866
0.767451823	30.9325428	4.464556694	5.378020763	0.913464069	73.98018646	21.67264557
NA	NA	NA	NA	NA	44.01804733	46.3145752
7.065162182	52.40736389	5.076483325	5.608891964	0.532408714	76.42329407	13.29528809
2.712668657	16.23099518	5.222835541	5.705188751	0.48235321	50.9336319	32.65420532
0.690056443	24.10489082	3.771246195	4.712906837	0.941660643	89.50328064	6.905204773
1.249764442	38.57919312	4.930744171	5.821277142	0.89053297	83.09567261	13.45552063
NA	NA	NA	NA	NA	17.25267029	57.8578186
1.396993399	40.80896378	5.27743042	5.549314022	0.276883602	79.07756042	14.36198425
2.527088165	21.2454567	5.139670849	5.554628849	0.414958	40.22866058	41.49605179
1.345047235	42.20755386	4.899044037	5.675926685	0.776882648	71.86551666	20.89916229
1.427649617	39.22254181	4.867054939	5.707252979	0.84019804	73.68249512	19.06717682
2.223632289	26.39917564	5.394762039	5.69751358	0.302751541	68.68928528	22.75042725

Table S4. Scores of climatic and soil variables on the first two axes of the redundancy analysis (RDA).

Table S4. Scores of climatic and soil variables on the first two axes of the redundancy analysis (RDA).		
RDA1	**RDA2**	**Variable**
-0.558831303	0.352772406	BIO4
-0.103452109	-0.244591803	BIO15
0.628081543	0.255953732	BIO12
0.697045513	-0.060844929	AWC
-0.174058386	-0.465200751	Bulk density
-0.095624735	0.05729109	CN
-0.26032554	0.54449289	Coarse frag
-0.038455408	-0.067012616	K
0.235357162	-0.239424178	pH

10. Praca nr 2:

Article

Leaf character variation does not consistently track molecular differentiation in selected *Alchemilla* L. species

Adrianna M. Kosiróg-Ceynowa[1,*], Magdalena Dudek[1,*], Iwona Jędrzejczyk[2], Julia Jaskólska[1], Dorota Łuszczek[3], Magdalena Narajczyk[3], Sławomir Nowak[1] and Dariusz L. Szlachetko[1]

[1] University of Gdańsk, Faculty of Biology, Department of Plant Taxonomy and Nature Conservation, Wita Stwosza 59, 80-308 Gdańsk, Poland; julia.jaskolska@phdstud.ug.edu.pl (J.J.); slawomir.nowak@ug.edu.pl (S.N.); dariusz.szlachetko@ug.edu.pl (D.L.S.)
[2] Bydgoszcz University of Science and Technology, Department of Biotechnology, Kaliskiego Ave. 7, 85-796 Bydgoszcz, Poland; jedrzej@pbs.edu.pl (I.J.)
[3] University of Gdańsk, Faculty of Biology, Bioimaging Laboratory, Wita Stwosza 59, 80-308 Gdańsk, Poland; dorota.luszczek@ug.edu.pl (D.Ł.); magdalena.narajczyk@ug.edu.pl (M.N.)
* Correspondence: magdalena.dudek@ug.edu.pl (M.D.); adriannakosirogceynowa@gmail.com (A.M.K.C.)

Abstract

Species identification within *Alchemilla* L. is challenging because of apomixis, polyploidy, hybridization, similar microspecies, and overlapping diagnostic characters. We evaluated whether leaf micromorphology, sequence variation, and nuclear DNA content provide congruent species-level patterns in European *Alchemilla* species. Leaf surfaces were examined by scanning electron microscopy, nuclear DNA content by flow cytometry, and sequence variation in the nuclear ribosomal internal transcribed spacer (ITS) and three plastid regions (*matK*, *rpoC1*, and *trnH-psbA*). Leaf micromorphology varied in the relative size of the apical tooth and trichome abundance and distribution. Three operational leaf-character combinations were distinguished, but none was restricted to a single morphologically identified species. Nuclear DNA content ranged from 3.52 to 3.72 pg/2C and overlapped extensively among taxa. ITS contained the highest proportion of variable and parsimony-informative sites and recovered broad-scale phylogenetic structure partly corresponding to the geographic origins of the included sequences. However, neither phylogenetic nor network analyses consistently resolved species-specific groups among the focal European taxa, and the plastid markers likewise showed limited discriminatory power. Overall, the datasets did not correspond consistently with morphological species identification. Leaf micromorphology, molecular markers, and genome-size

estimates should therefore be regarded as complementary rather than independently diagnostic evidence in European *Alchemilla*.

Keywords: *Alchemilla*; apomixis; polyploidy; leaf micromorphology; trichomes; ITS; plastid markers; flow cytometry; genome size; integrative taxonomy

1. Introduction

Alchemilla L., commonly known as lady's mantle, comprises herbaceous plants belonging to the family Rosaceae Juss. Depending on the taxonomic treatment, the genus is estimated to comprise approximately 1000 species worldwide, including 300-400 species occurring in Europe [1-3]. In Poland, 58 species have been recognized [4,5]. Despite its considerable diversity, species delimitation within *Alchemilla* remains particularly challenging, largely due to apomixis, high levels of polyploidy, occasional hybridization, and the occurrence of numerous morphologically similar microspecies [1].

Apomictic reproduction has long been recognized as a characteristic feature of the genus *Alchemilla* [6,1]. In many *Alchemilla* species, seeds develop without fertilization, while viable pollen production may be strongly reduced or absent [1,7,8]. Consequently, sexual reproduction is thought to play only a limited role in many lineages. Nevertheless, the production of at least partly viable pollen has been reported in some microspecies, indicating that occasional sexual reproduction and hybridization cannot be excluded [7]. Such events, combined with the subsequent fixation of genotypes through apomixis, may contribute to the origin and persistence of new apomictic lineages [1,9]. This reproductive system can generate numerous closely related and morphologically similar entities, thereby complicating the recognition of species boundaries.

Traditional morphological approaches remain the primary basis for the identification of *Alchemilla* species, but their application is frequently complicated by subtle differences among taxa and the overlap of diagnostic character states. This difficulty may be further increased by intraspecific phenotypic variation and by the large number of closely related microspecies [1,7,5].

Consequently, individual morphological characters may not always provide unambiguous boundaries among closely related taxa, and reliable identification generally requires the combined evaluation of multiple morphological characters [10,11].

Molecular approaches have provided important insights into the evolutionary history of *Alchemilla*, but the resolution of closely

related species remains limited [1,12]. Standard plastid DNA barcodes, including *rbcL* and *matK*, frequently show insufficient variation to discriminate closely related plant species when applied individually [13-15]. Similar limitations have also been observed in *Alchemilla*, where molecular phylogenetic studies have resolved major evolutionary lineages, while relationships among some closely related taxa remain poorly resolved [1,12]. Despite the widespread application of standard DNA barcode regions in plants, comparative multilocus studies combining nuclear ITS with plastid markers such as *matK*, *trnH-psbA* and *rpoC1* remain limited in *Alchemilla.*

Nuclear ITS generally provides greater sequence variation than standard plastid barcodes. However, in apomictic and polyploid plant complexes, hybridization, reticulate evolution, incomplete lineage sorting, and the complex evolution of multicopy nrDNA may obscure the correspondence between gene trees and species boundaries [16-19]. The extent to which sequence differentiation in nuclear and plastid regions corresponds to morphologically recognized *Alchemilla* species and to variation in leaf morphology and micromorphology therefore remains insufficiently understood.

Micromorphological analyses using scanning electron microscopy (SEM) provide an additional source of potentially informative taxonomic characters. SEM enables the detailed examination of epidermal surfaces and other fine-scale structures that may provide valuable characters for taxonomically informative characters [20,21]. Across Rosaceae, traits such as trichome morphology and distribution [22,23], epidermal cell structure [24,25], stomatal characteristics [26,24], and epicuticular wax deposition [23,21] may differ among related taxa and support their taxonomic characterization. In *Alchemilla*, studies focused on leaf micromorphology remain limited. The available study examined foliar epidermal structure and trichome distribution in *Alchemilla*, primarily in species occurring in Iran [21]. It documented interspecific variation in epidermal and indumentum characters and suggested that some of these traits may have taxonomic value. However, it remains unclear whether leaf micromorphological characters are consistent within species and correspond to patterns of molecular differentiation in *Alchemilla*.

Given the taxonomic complexity of *Alchemilla*, comparisons among complementary morphological, molecular and cytometric datasets may help determine whether characters observed at different organizational levels support the same taxonomic structure. In particular, it remains unclear whether variation in leaf morphological and micromorphological characters corresponds to differentiation in standard nuclear and plastid DNA regions or to differences in nuclear DNA content. Evaluating this correspondence is important for assessing the taxonomic significance of micromorphological characters while avoiding

overreliance on any single source of evidence in taxonomic assessment [27-29].

The aim of this study was to characterize leaf morphological and micromorphological leaf variation using scanning electron microscopy in selected *Alchemilla* species collected in Poland and to assess whether the observed character states corresponded to morphological species assignments. A further objective was to characterize sequence variation and assess species-level resolution in the nuclear ITS region and three plastid regions (*matK, rpoC1* and *trnH-psbA*) and assessed whether the resulting molecular patterns were broadly congruent with the distribution of leaf-characters states among the same morphologically identified species. Nuclear DNA content was also estimated using flow cytometry to assess whether genome-size estimates differed among morphologically identified species and showed broad correspondence with the species-level patterns of leaf-character variation.

2. Results

2.1. Leaf Micromorphology (SEM)

2.1.1. Apical tooth morphology

The apical region of the leaf lobe was characterized by a distinct apical tooth flanked by adjacent marginal teeth (Figure 1A-B). Examination of low-magnification SEM images revealed two states based on the relative size of the apical tooth compared with the adjacent marginal teeth. An apical tooth smaller than the adjacent marginal teeth was recorded in 21 of the 27 examined SEM samples (77.8%) and represented the most frequent condition (Figure 1A). A larger apical tooth was recorded in six SEM samples (22.2%) (Figure 1B). Neither of the two apical-tooth states was restricted to a single morphologically identified species.

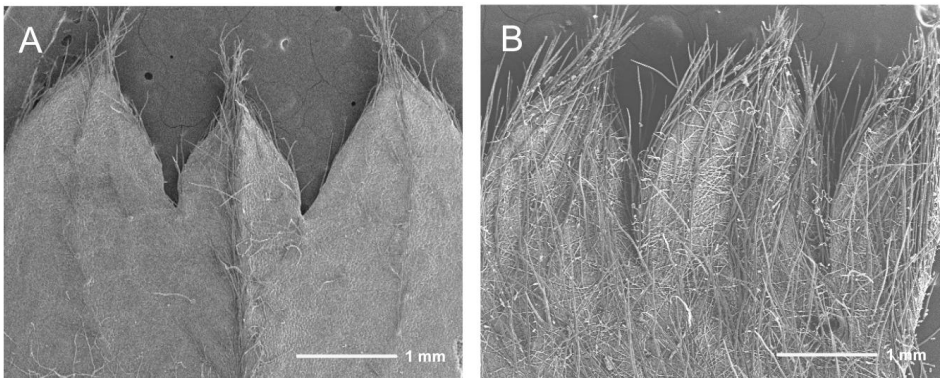


Figure 1. SEM images showing variation in the relative size of the apical tooth compared with the adjacent marginal teeth: (**a**) *Alchemilla glabra* (SEM no. 1) apical tooth smaller than the adjacent marginal teeth; (**b**) *A. monticola* (SEM no. 24) apical tooth larger than the adjacent marginal teeth.

2.1.2. Trichome morphology and distribution

Trichome abundance and distribution varied among the examined SEM samples. Two qualitative categories of trichome abundance were recognized: sparse and dense indumentum. Sparse indumentum was characterized by relatively low trichome abundance within the examined leaf fragment, whereas dense indumentum was characterized by numerous trichomes forming a more extensive cover. Trichome distribution was assessed separately from abundance. Based on these operational categories, dense indumentum was recorded in 14 of the 27 examined SEM samples (51.9%), whereas sparse indumentum occurred in 13 samples (48.1%). Among the 23 SEM samples for which both adaxial and abaxial surfaces could be evaluated, the same trichome-abundance category was recorded on both surfaces.

Trichomes occurred on the lamina, veins, and leaf margins, but their distribution differed among SEM samples. On the adaxial surface, trichomes were restricted predominantly to the leaf margins and/or veins in 8 of 26 assessable SEM samples (30.8%), whereas in 18 samples (69.2%) they were also distributed across the lamina. The adaxial surface could not be assessed in one SEM sample because suitable images were unavailable. On the abaxial surface, trichomes were restricted predominantly to the leaf margins and/or veins in 5 of 24 assessable samples (20.8%), whereas in 19 samples (79.2%) they were also distributed across the lamina. The abaxial surface could not be assessed in three SEM samples because suitable images were unavailable or the surface could not be evaluated reliably. Among the 23 SEM samples for which both surfaces could be assessed, 22 (95.7%) showed the

same general trichome-distribution pattern on the adaxial and abaxial surfaces. Neither trichome abundance nor the general distribution pattern was restricted to a single morphologically identified species.

Two principal structural categories of trichomes were observed: cylindrical unicellular trichomes (Figure 3A) and clavate-cylindrical multicellular trichomes (Figure 3B). Cylindrical unicellular trichomes were recorded in all 27 examined SEM samples. In three samples (11.1%), only unicellular trichomes were observed, whereas unicellular and multicellular trichomes cooccurred in the remaining 24 samples (88.9%). Multicellular trichomes varied in the number of constituent cells, ranging from two to eight cells among the examined samples. This variation was treated as within-category variation and was recorded descriptively rather than used to distinguish additional trichome morphotypes. In some samples, cylindrical unicellular trichomes arose from multicellular basal epidermal complexes. Detailed observations for individual SEM samples are provided in Table S2.

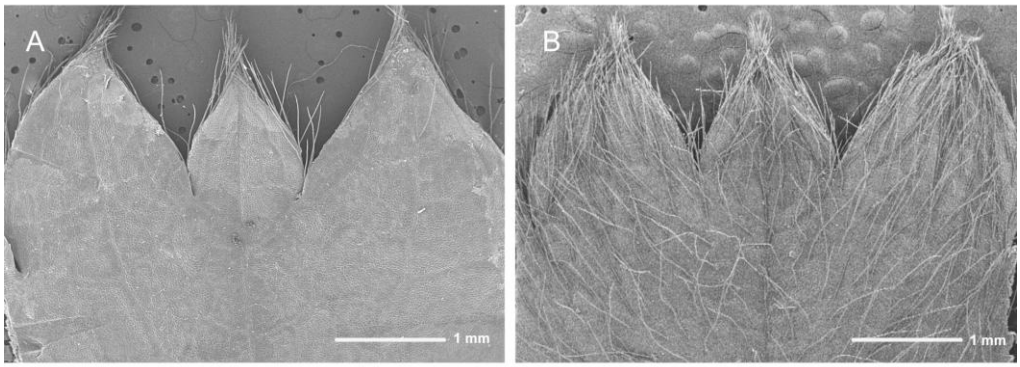


Figure 2. Representative SEM images showing variation in trichome abundance: (**a**) *A. glabra* (SEM no. 14) sparse indumentum; (**b**) *A. glaucescens* (SEM no. 11) dense indumentum.

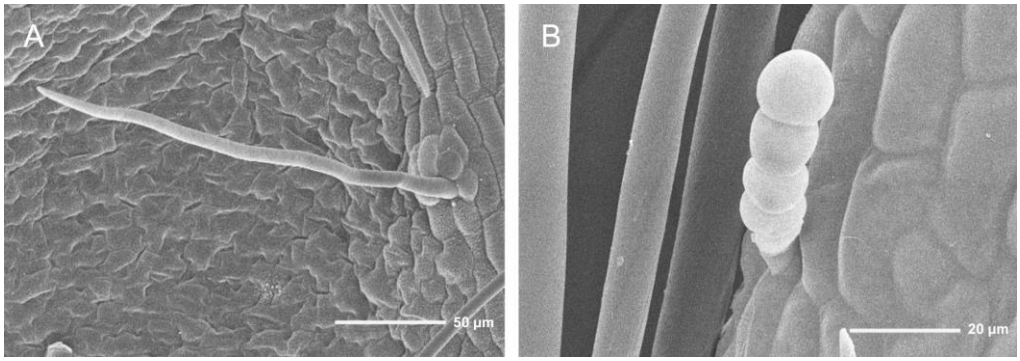


Figure 3. Representative SEM images showing the two principal structural categories of trichomes: (**a**) *A. glaucescens* (SEM no. 3) cylindrical unicellular; (**b**) *A. glabra* (SEM no. 7) clavate-cylindrical multicellular.

2.1.3. Epidermal cell characteristics

The epidermal organization of the examined leaf surfaces was broadly similar among the SEM samples. Epidermal cells were irregularly polygonal in 22 of the 27 examined samples (81.5%). In three samples (11.1%), epidermal cells ranged from irregularly polygonal to subisodiametric, whereas in two samples (7.4%) elongate-polygonal cells occurred together with irregularly polygonal cells. Anticlinal wall outline showed some variation among samples, ranging from straight to slightly sinuate to distinctly sinuate (Figure 4). In one sample, the anticlinal walls could not be assessed reliably because they were obscured by abundant epicuticular wax deposits and fungal hyphae. The recorded variation in epidermal cell shape and anticlinal wall outline did not show a consistent correspondence with morphological species identification. Detailed observations for individual SEM samples are provided in Table S2. Epidermal cell characteristics were retained as descriptive observations and were not used to define the three operational leaf-character combinations.

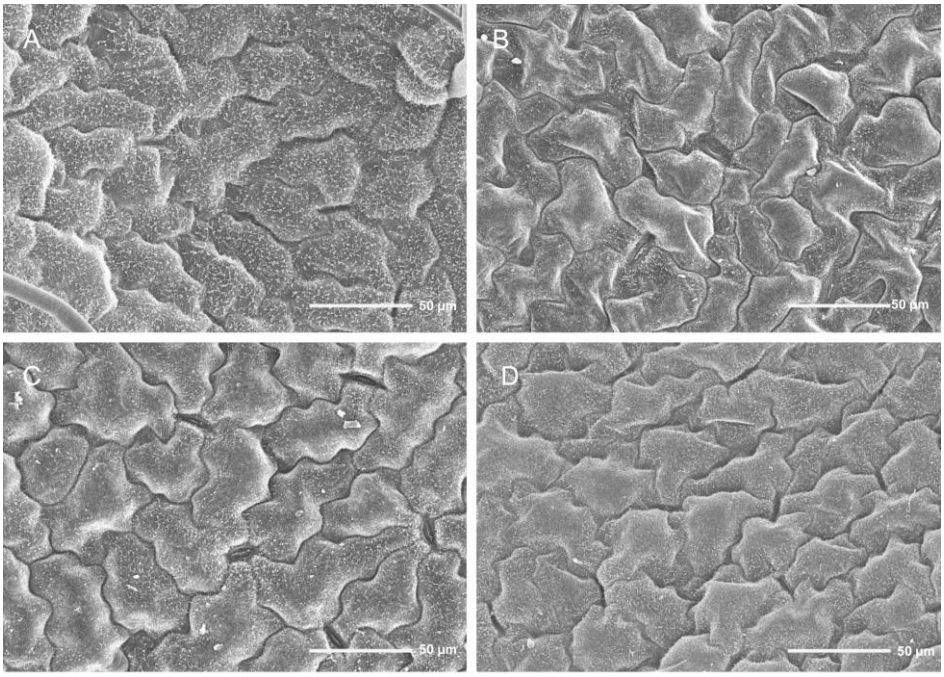


Figure 4. Representative SEM images showing epidermal cell characteristics on the abaxial leaf surface of selected *Alchemilla* samples: (**a**) *A. hirsuticaulis* (SEM no. 6) irregularly polygonal epidermal cells with slightly to moderately sinuate anticlinal walls; (**b**) *A. subcrenata* (SEM no. 4) irregularly polygonal epidermal cells with distinctly sinuate anticlinal walls; (**c**) *A. glabra* (SEM no. 1) irregularly polygonal epidermal cells with distinctly sinuate anticlinal walls; (**d**) *A. glaucescens* (SEM no. 3) irregularly polygonal epidermal cells with slightly to moderately sinuate anticlinal walls.

2.1.4. Stomatal characteristics and epicuticular wax

Stomatal morphology and distribution showed qualitative variation among the examined SEM samples. Stomata could be assessed reliably in 24 of the 27 samples. Narrowly elliptic stomata were recorded in 18 of the 24 assessable samples (75.0%), whereas elliptic to narrowly elliptic stomata occurred in six samples (25.0%). Based on the qualitative categories recorded in Table S2, sparse stomata were observed in 15 of the 24 assessable samples (62.5%), whereas numerous stomata were recorded in nine samples (37.5%). Sparse stomata frequently occurred in distinct clusters, although irregular distribution was also observed, whereas numerous stomata were generally densely or evenly distributed. Because the available SEM images were not obtained under fully standardized magnification and field-of-view conditions, stomatal abundance and distribution were treated as qualitative descriptive characters rather than subjected to quantitative comparison. Where assessable, subsidiary cells were weakly differentiated or not distinctly differentiated from the surrounding epidermal cells.

Variation was also observed in the abundance and distribution of epicuticular wax. Epicuticular wax could be assessed in 25 of the 27 SEM samples. Abundant or very abundant wax deposition was recorded in 15 samples (60.0%), moderate deposition in six samples (24.0%), and scarce deposition in four samples (16.0%). In two samples, epicuticular wax could not be assessed because suitable SEM images were unavailable. Scarce wax deposits were generally restricted to the vicinity of the stomatal complex and adjacent epidermal cells (Figure 5A), whereas abundant to very abundant deposits formed dense reticulate coatings around stomatal complexes and the surrounding epidermal surface (Figure 5B). Stomatal and epicuticular wax characteristics were retained as descriptive observations and were not used to define the three operational leaf-character combinations.

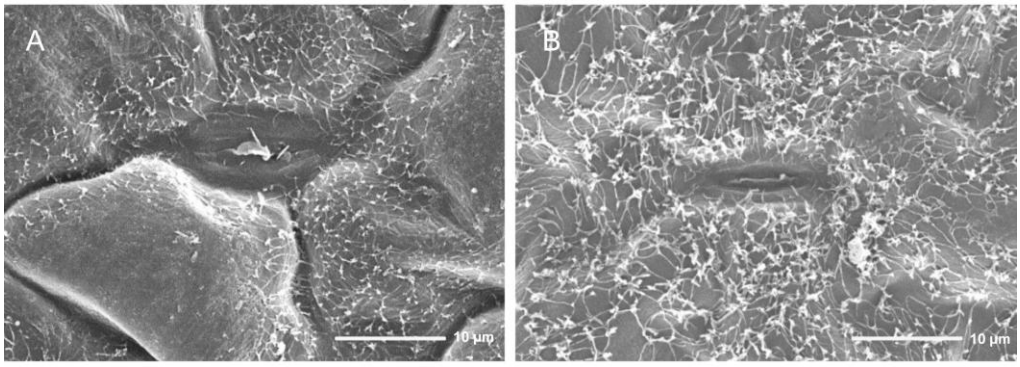


Figure 5. Representative SEM images showing variation in epicuticular wax deposition on the abaxial leaf surface: (**a**) *A. subcrenata* (SEM no. 4) scarce epicuticular wax deposition around the stomatal complex; (**b**) *A. hirsuticaulis* (SEM no. 6) abundant epicuticular wax deposition forming a dense reticulate coating around the stomatal complex and adjacent epidermal cells.

2.1.5. Recurrent combinations of leaf characters

Based on the combination of the relative size of the apical tooth and trichome abundance, three operational leaf-character combinations, designated Types I-III, were distinguished among the 27 examined SEM samples (Table 1). Type I was characterized by an apical tooth smaller than the adjacent marginal teeth and sparse indumentum, whereas Type II combined an apical tooth smaller than the adjacent marginal teeth with dense indumentum. Type III was characterized by an apical tooth larger than the adjacent marginal teeth and dense indumentum. No SEM sample combined an apical tooth larger than the adjacent marginal teeth with sparse indumentum.

These combinations were introduced as an operational means of summarizing recurrent patterns in the examined material and should not be interpreted as representing natural or taxonomically discrete groups. Epidermal cell morphology, stomatal characteristics, and epicuticular wax deposition were retained as descriptive observations and were not used to define the three leaf-character combinations.

Type I represented the most frequently observed combination and was recorded in 13 of the 27 SEM samples (48.1%). Type II occurred in eight samples (29.6%), whereas Type III was recorded in six samples (22.2%). None of the three leaf-character combinations was restricted to a single morphologically identified species. Conversely, several species were represented by more than one leaf-character combination. Species represented by only one or two SEM samples did not permit reliable assessment of the intraspecific stability of the recorded character combinations. The defining character states and distribution of the three operational leaf-character combinations among morphologically identified species are summarized in Table 1.

Table 1. Distribution of the three recurrent operational leaf-character combinations among the morphologically identified *Alchemilla* species. Values indicate the number of SEM samples assigned to each leaf-character combination. Each SEM sample was assigned to one combination only. Types I-III were distinguished based on the relative size of the apical tooth and trichome abundance.

Species	Type I	Type II	Type III	Total
Alchemilla glabra Neygenf.	6	2	1	**9**
Alchemilla glaucescens Wallr.	2	3	3	**8**
Alchemilla gracilis Opiz	2	0	0	**2**
Alchemilla hirsuticaulis H. Lindb.	0	1	0	**1**
Alchemilla mollis (Buser) Rothm.	0	2	0	**2**
Alchemilla monticola Opiz	1	0	1	**2**
Alchemilla subcrenata Buser	2	0	0	**2**
Alchemilla subglobosa C.G. Westerl.	0	0	1	**1**
Total	**13**	**8**	**6**	**27**

2.2. Flow cytometric estimation of nuclear DNA content

Nuclear DNA content of the investigated *Alchemilla* accessions ranged from 3.52 to 3.72 pg/2C, corresponding to 3443-3638 Mbp (Table S7). The highest mean 2C nuclear DNA content was recorded in *A. glaucescens* from Rąb (3.72 pg), followed by the Osowa accession of the same species (3.71 pg), whereas the lowest value was observed in *A. hirsuticaulis* from Krokowa (3.52 pg). The *A. hirsuticaulis* accession differed significantly from both *A. glaucescens* accessions from Rąb and Osowa according to the Newman-Keuls post hoc test, whereas all remaining accessions formed an overlapping intermediate group. Within *A. glaucescens*, mean 2C nuclear DNA content ranged from 3.63 pg in the Henrykowo and Kochanowo accessions to 3.72 pg in the Rąb accession, while the Gile accession showed an intermediate value of 3.69 pg. The *A. gracilis* accessions showed similar values, ranging from 3.60 pg in Witów to 3.67 pg in Wirty. Similarly, *A. glabra* accessions displayed limited variation, with mean values ranging from 3.56 to 3.63 pg/2C. The two *A. mollis* accessions, collected in Chrząstawa Mała and Gdańsk-Oliwa, showed mean 2C nuclear DNA contents of 3.69 and 3.58 pg, respectively, and both were assigned to the same overlapping statistical group. Among taxa represented by a single sampling locality, *A. subcrenata*, *A. monticola*, and *A. subglobosa* had intermediate mean 2C nuclear DNA contents of 3.69, 3.58, and 3.56 pg, respectively.

2.3. Molecular Analyses

2.3.1. Molecular dataset characteristics

A total of 177 new *Alchemilla* sequences were generated, including 40 ITS, 46 *matK*, 43 *trnH-psbA*, and 48 *rpoC1* sequences. These sequences represented 49 individually coded plants belonging to eight morphologically identified species. Sequences for all four regions were obtained for 34 individuals, whereas the remaining 15 plants lacked sequences for one or more loci because the corresponding chromatograms were of insufficient quality for reliable sequence determination. The number and identity of successfully sequenced loci for each individually coded plant are provided in Table S5.

Within the assembled datasets, ITS contained the greatest number and proportion of variable and parsimony-informative sites and provided the most resolved phylogenetic reconstruction among the four analysed regions (Figure 6). Although the *matK* dataset contained 61 variable sites, including 24 parsimony-informative sites, its phylogenetic reconstruction showed less resolution among the focal sequences than the ITS

tree. The phylogenetic reconstructions based on the shorter *trnH-psbA* alignment and the comparatively conserved *rpoC1* region showed similarly limited resolution among the focal sequences.

Because the ITS dataset combined the greatest observed sequence variability, the broadest taxon sampling, and the most resolved topology among the analysed datasets, its phylogenetic reconstruction is presented in the main text (Figure 7). Trees inferred separately from the three plastid regions are provided in the Supplementary Materials: *matK* (Figure S2), *rpoC1* (Figure S3), and *trnH-psbA* (Figure S4).

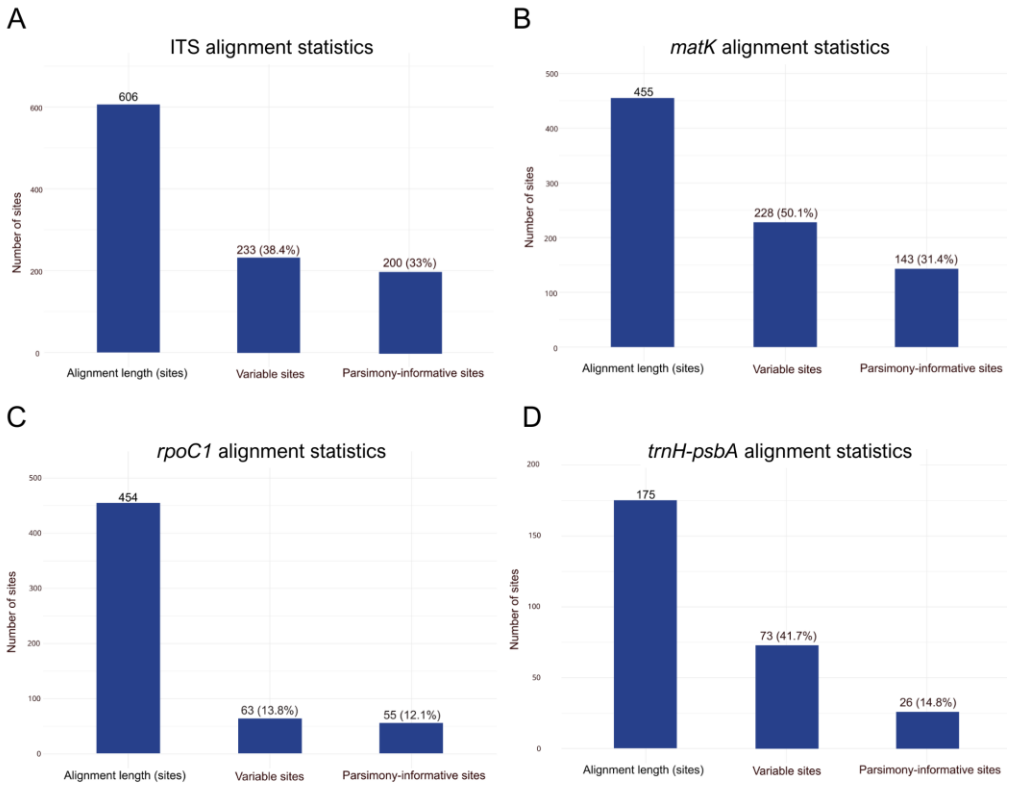


Figure 6. Summary of sequence variation across the four analysed markers. For each marker, the alignment length, number of variable sites, and number of parsimony-informative sites are shown. Panels: (**a**) ITS; (**b**) *matK*; (**c**) *rpoC1*; (**d**) *trnH-psbA*.

2.3.2. Phylogenetic reconstruction

The ITS phylogenetic dataset comprised 217 sequences, representing 91 *Alchemilla* species and one *Comarum palustre* L. sequence used as the outgroup. The topology presented here was inferred using Maximum Likelihood (ML), with node support indicated by ML bootstrap percentages and Bayesian posterior probabilities for corresponding nodes (Figure 7). Compared with the plastid datasets, the ITS dataset included substantially more sequences and,

under the present sampling, yielded a more resolved phylogenetic topology (Table 2; Figure 7).

Table 2. Sequence variability and data completeness of the four molecular datasets analyzed in this study.

Marker	Total sequences (n)	Sequences generated in this study (n)	Nucleotide Diversity (π)	Missing Data (N)	Missing data (%)
ITS	217	40	0.07433	288	0.22
matK	95	46	0.02571	405	0.95
trnH-psbA	61	43	0.0446	52	0.49
rpoC1	64	48	0.03559	572	2.00

The ITS tree recovered broad-scale geographic structure within the genus (Figure 7). Two major clades were recovered. Clade A (BS=100; PP=1.0) comprised predominantly African taxa, whereas clade B (BS=96; PP=0.99) contained two principal subclades. The first of these, clade C, comprised predominantly Eurasian representatives of the genus, whereas clade D (BS=93; PP=1.0) comprised predominantly American taxa. The predominantly Eurasian clade C included two supported subclades, designated C1 and C2 (BS=99; PP=1.0 for each).

All ITS sequences generated in the present study were positioned within the predominantly Eurasian clade C (Figure 7). However, the focal species represented by multiple newly generated ITS sequences were not consistently recovered as monophyletic or otherwise exclusive groups. Sequences from individuals identified as *A. glabra, A. glaucescens, A. gracilis, A. hirsuticaulis, A. mollis, A. subcrenata* and *A. subglobosa* were interspersed with sequences assigned to other focal species and with GenBank-derived sequences representing other Eurasian *Alchemilla* taxa. No reliable ITS sequence was obtained for the two sampled *A. monticola* plants; consequently, this species was not represented among the newly generated ITS sequences.

Because the study focused on the relationships among the focal Eurasian individuals, clades A, C1, and D were collapsed in Figure 7 to improve the visibility of relationships within subclade C2, which contained all ITS sequences generated in the present study. The complete, uncollapsed ITS tree is provided in Figure S1, and the taxonomic composition of the collapsed clades are listed in Table S8. The majority of smaller clades within subclade C2 (Figure 7) received insufficient statistical support, based on both bootstrap values and posterior probabilities. A large unresolved polytomy was also present within subclade C2. Consequently, relationships among many focal and other Eurasian sequences within C2 could not be resolved confidently using ITS alone.

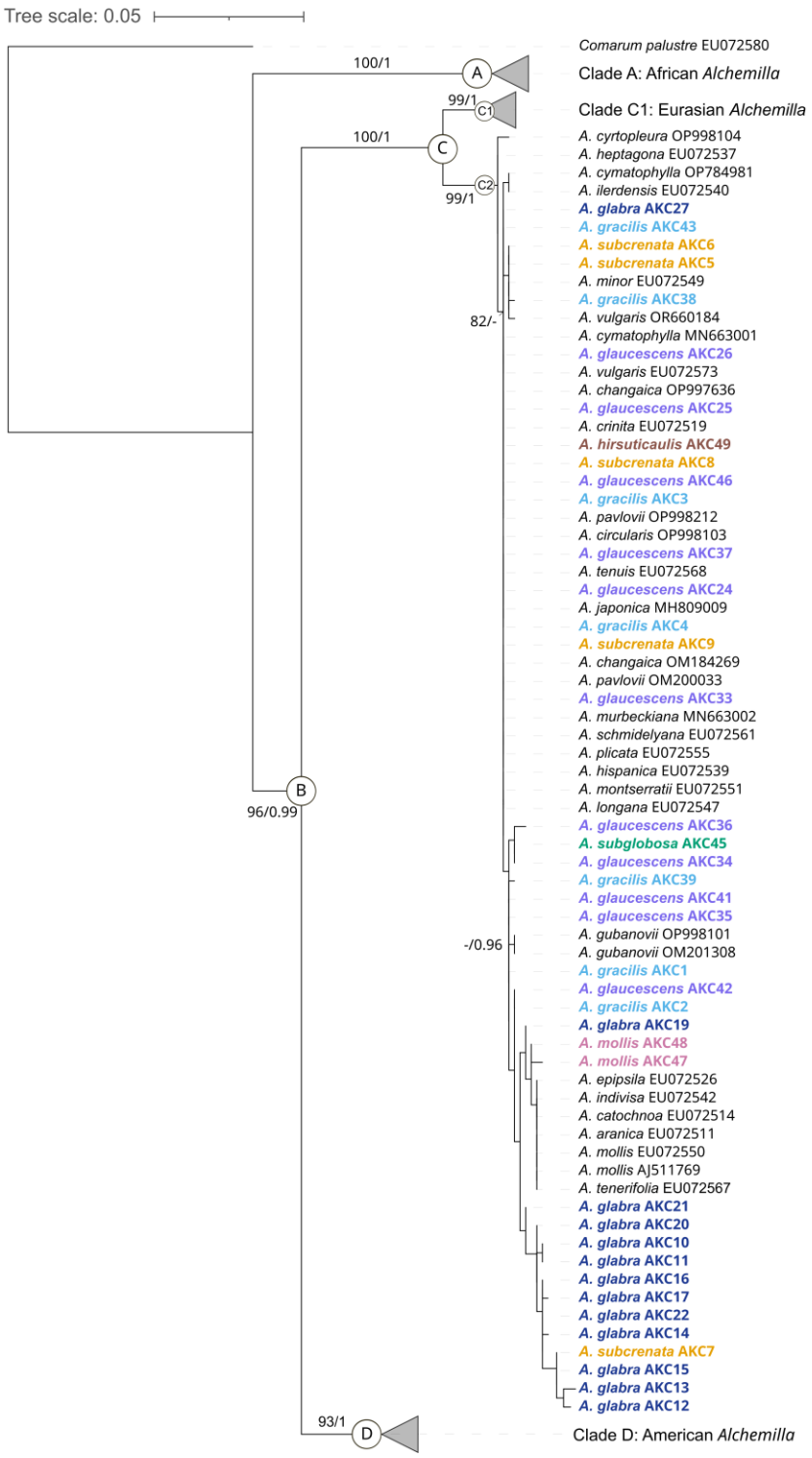


Figure 7. Maximum-likelihood phylogeny of *Alchemilla* inferred from the ITS dataset. Values at nodes represent bootstrap support (BS) and Bayesian posterior probabilities (PP), respectively. Only BS values ≥ 75 and PP values ≥ 0.95 are shown. Major clades are indicated by capital letters enclosed in circles at the corresponding nodes. Clades A, C1, and D were collapsed to facilitate visualization of subclade C2 containing the sequences generated in the present study. Taxa included in the collapsed clades are listed in Table S8.

2.3.3. Network and haplotype analyses

The NeighborNet analysis of 216 ITS sequences representing 91 *Alchemilla* species produced a complex unrooted split network with three visually distinguishable main regions (Figure 8). The network had a fit value of 99.9, showing that it closely represented the pairwise-distance matrix; however, this value should not be interpreted as statistical branch support. At a broad geographical scale, one region comprised predominantly African taxa, another comprised predominantly American taxa, and the third comprised predominantly Eurasian taxa. All sequences generated in this study were located within the Eurasian region of the network together with reference sequences retrieved from GenBank. A similar broad geographical pattern was also observed in the ITS phylogenetic tree.

Within the Eurasian region, clearly separated species-specific groups were not recovered. Sequences identified as the same species were often located in different parts of the Eurasian region, particularly in *Alchemilla gracilis*, *A. glaucescens*, *A. subcrenata*, and *A. glabra*. Conversely, sequences belonging to different species were frequently occurred in close proximity within the displayed network. Most sequences generated in this study occurred within a relatively compact region of the network together with several Eurasian reference sequences. This region contained sequences assigned to *A. glaucescens*, *A. subcrenata*, *A. gracilis*, *A. glabra*, and *A. hirsuticaulis*. The two newly generated *A. mollis* sequences (AKC47 and AKC48) were located close to GenBank-derived reference sequences assigned to the same species. However, this local proximity did not constitute a species-exclusive region of the network. This pattern indicated limited correspondence between morphological species assignments and the ITS distance structure of the focal sequences.

Parallel splits and box-like structures were visible in several parts of the network, indicating incompatible distance signals that could not be represented by a single strictly bifurcating topology. The NeighborNet analysis did not allow the source of these incompatible signals to be determined. To examine exact ITS sequence sharing and mutational relationships within the Eurasian assemblage, a selected subset of sequences was analysed using a TCS haplotype network (Figure 9).

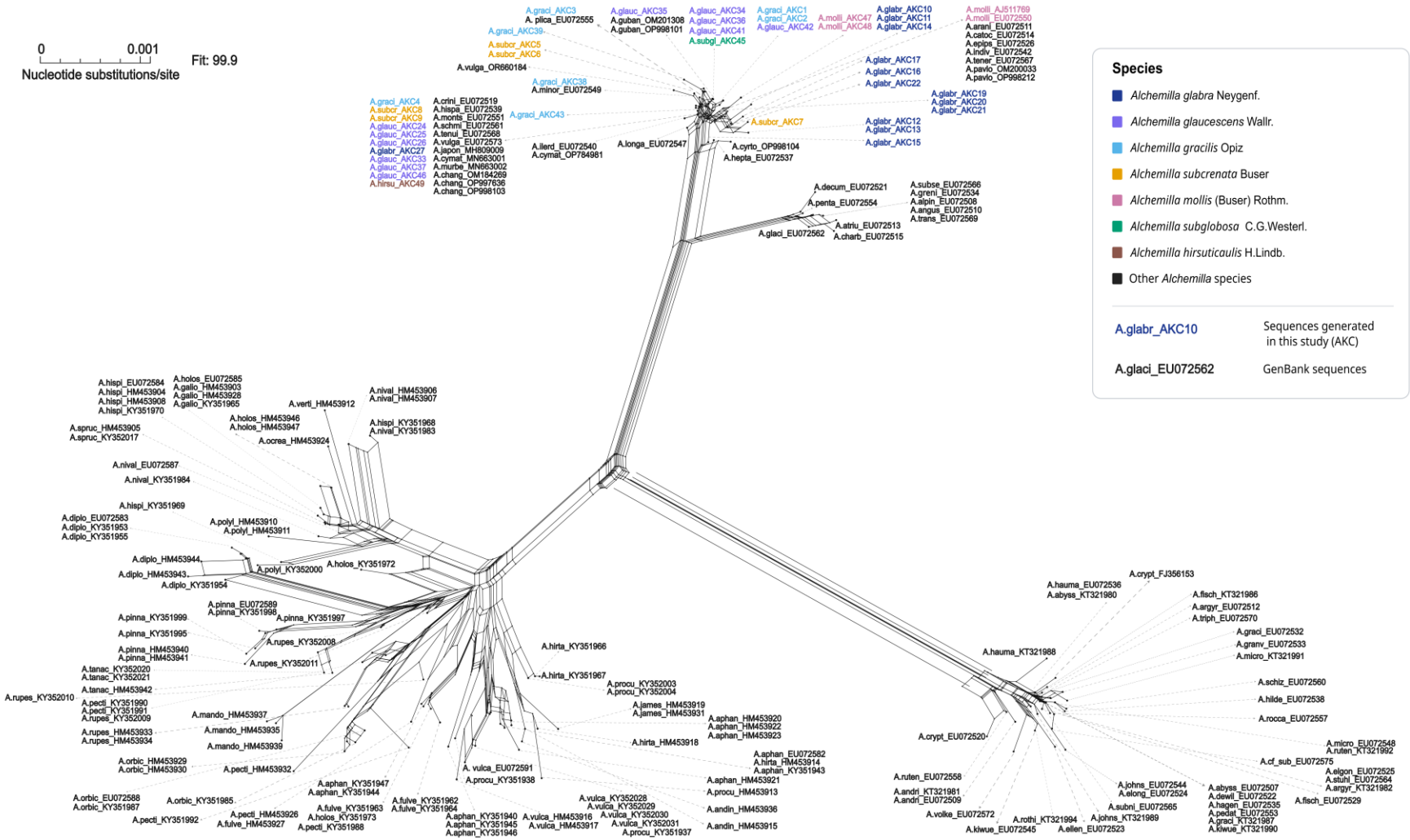


Figure 8. NeighborNet phylogenetic network based on ITS sequences of *Alchemilla*

The TCS haplotype network of the selected Eurasian ITS sequences showed extensive haplotype sharing among morphologically identified taxa (Figure 9). The most frequent haplotypes contained sequences generated in the present study identified as *A. glaucescens*, *A. hirsuticaulis*, *A. subcrenata*, *A. gracilis*, and *A. glabra*, together with numerous GenBank-derived sequences assigned to other Eurasian *Alchemilla* species. Another haplotype was shared by *A. subcrenata* AKC7 and several *A. glabra* individuals, whereas a further haplotype contained sequences identified as *A. gracilis*, *A. glaucescens*, and *A. subglobosa*.

The two sequences of *A. mollis* generated in this study (AKC47 and AKC48) shared the same haplotype, which was separated by a single mutational step from haplotype containing, GenBank-derived *A. mollis* sequences together with sequences assigned other Eurasian taxa. Thus, the newly generated *A. mollis* sequences did not share an identical ITS haplotype with the GenBank-derived records of the same species. The same *A. mollis* haplotype was also separated by a single mutational step from a haplotype containing several *A. glabra* sequences generated in this study. Thus, the TCS network did not show clear species-specific separation among the focal taxa, as identical ITS haplotypes were shared among sequences assigned to different species.

Both network analyses showed a limited species-level structuring among the focal Eurasian ITS sequences. Morphologically identified species did not occupy clearly separated regions of the NeighborNet network, and several TCS haplotypes were shared among sequences assigned to different species.

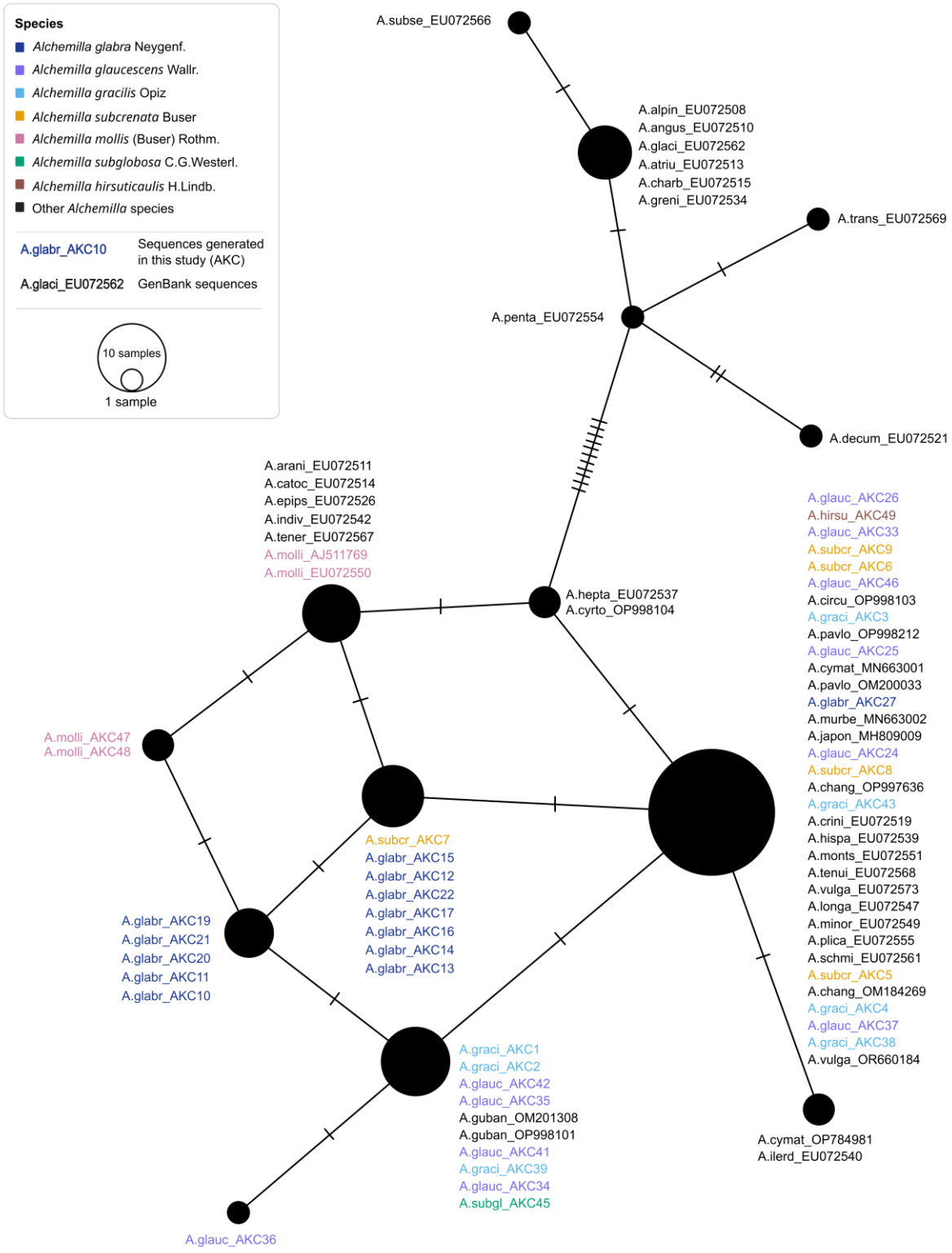


Figure 9. TCS haplotype network based on selected Eurasian ITS sequences of *Alchemilla*.

3. Discussion

The present study revealed considerable variation in leaf morphological and micromorphological characters among the examined *Alchemilla* SEM samples, but this variation did not correspond consistently to morphological species identification. Similarly, molecular analyses did not provide consistent species-level discrimination among the focal taxa, while 2C nuclear DNA content showed extensive overlap among the examined taxa. Overall, when considered at the species level, none of the investigated datasets consistently reflected the boundaries of the morphologically identified species. However, this lack of correspondence should not be interpreted as evidence that the recognized taxa lack biological differentiation.

SEM analyses revealed variation in several leaf-surface characters, most clearly in the relative size of the apical tooth and in trichome abundance and distribution, whereas variation in epidermal cell morphology, stomatal features, and epicuticular wax deposition did not form consistent species-specific among the examined SEM samples. Previous studies have reported that leaf indumentum, epidermal characters, stomatal features, and epicuticular waxes may provide taxonomically informative characters in Rosaceae, including Potentilleae and *Alchemilla* [21-24]. In the present study, however, none of the observed character states or the three operational combinations based on apical-tooth size and trichome abundance was restricted to a single morphologically identified species.

Variation in the relative size of the apical tooth compared with the adjacent marginal teeth represented an additional operational leaf character that could be assessed in all examined SEM samples. Two states were observed: an apical tooth smaller than or larger than the adjacent marginal teeth. Together with trichome abundance, this character defined three operational leaf-character combinations. However, none of these combinations was restricted to a single morphologically identified species, and several species were represented by more than one combination. The relative size of the apical tooth may therefore contribute to the morphological characterization of the examined material, but its independent diagnostic value and within-species stability remain uncertain because of the limited and unequal sampling. The absence of samples combining a larger apical tooth with sparse indumentum should likewise be treated as a feature of the examined dataset rather than evidence of a fixed biological association between these characters. Characters of the marginal teeth, including the relative size of the apical tooth compared with adjacent teeth, have previously been used in species descriptions and taxonomic comparisons within *Alchemilla* [30,31]. The three combinations should therefore be regarded as a descriptive

summary of recurrent variation rather than as taxonomically discrete groups.

Trichome abundance and distribution varied markedly among the examined SEM samples, whereas the two principal structural categories were broadly shared among species. Two principal structural categories, cylindrical unicellular and clavate-cylindrical multicellular trichomes, were observed, whereas variation in the number of cells forming multicellular trichomes was treated as within-category variation. The extensive overlap of trichome characters among species suggests that indumentum may be more useful for documenting leaf-surface variation and contributing to multicharacter identification than for unambiguous species identification when used alone. The taxonomic importance of trichome characters has also been reported in Potentilleae and other Rosaceae [22-25]. However, because indumentum characters may also vary with leaf developmental stage and environmental conditions, the observed within-species variation cannot be interpreted as taxonomically meaningful without replicated sampling under standardized conditions [32,33].

Epidermal organization was broadly similar among the examined SEM samples. Most samples were characterized by irregularly polygonal epidermal cells, whereas irregularly polygonal to subisodiametric or elongate-polygonal cells occurred only in a small proportion of the material. Anticlinal wall outline also varied, ranging from straight or slightly sinuate to distinctly sinuate, but no recurrent species-specific pattern was identified. Comparable variation in foliar epidermal characters has previously been reported in *Alchemilla* and other Rosaceae [21,24]. Stomatal morphology showed relatively limited differentiation, whereas the apparent abundance and distribution of stomata varied qualitatively among samples, However, their potential diagnostic value could not be evaluated quantitatively because the available SEM images were not obtained under fully standardized magnification and field-of-view conditions. Apparent epicuticular wax coverage ranged from scarce to very abundant, with the recorded states overlapping among morphologically identified species. Variation in stomatal and epicuticular wax characters has also been documented in Rosaceae [23,24]. Because wax coverage was assessed qualitatively and may have been affected by sample preparation, these observations should be interpreted as descriptive rather than quantitative. Taken together, epidermal, stomatal, and epicuticular wax characters contributed to the description of leaf-surface variation but were not sufficiently consistent to distinguish the investigated species when used independently.

Among the examined molecular datasets, ITS contained the highest proportion of variable and parsimony-informative sites and produced the most resolved overall phylogenetic reconstruction. Nevertheless, its greater sequence variation and

phylogenetic resolution did not translate into consistent species-level discrimination. The plastid markers *matK*, *trnH-psbA*, and *rpoC1* likewise provided limited resolution among the focal sequences. However, direct comparisons among markers should be interpreted cautiously because the corresponding datasets differed in alignment length, number of sequences, taxonomic coverage and proportion of missing data. Variable performance of nuclear and plastid barcodes has also been reported across Rosaceae. In a broad family-level analysis, ITS2 showed higher species-discrimination performance than *matK*, *rbcL*, and *rpoC1*, although it did not provide perfect species-level identification [14]. Likewise, in *Fragaria*, previous analyses based on ITS and plastid regions such as *psbA-trnH* did not completely distinguish among species, illustrating the limitations of commonly used barcode regions in closely related Rosaceae taxa [34]. Similar difficulties in resolving relationships within *Alchemilla* using nuclear and plastid markers have been reported previously [1,12].

The ITS dataset recovered-scale phylogenetic structure corresponding partly to the major geographic regions represented in the dataset, whereas relationships among the focal European sequences remained weakly resolved. The focal species represented by multiple ITS sequences were not consistently recovered as exclusive lineages, and a large unresolved polytomy was present within the Eurasian part of the tree. This indicates that ITS contains phylogenetic signal at broader evolutionary scales but provides limited resolution among closely related European taxa. The contrast between deeper geographic structure and weak resolution among the focal taxa may reflect both the properties of the ITS marker and the complex evolutionary history of European *Alchemilla* [1,35].

The NeighborNet analysis was broadly consistent with the ITS phylogenetic reconstruction. The network contained major regions corresponding broadly to the geographic origin of the included sequences, whereas the European taxa showed considerable overlap and did not occupy clearly separated species-specific regions. Sequences assigned to different species were often located close to one another, and sequences identified as the same species were not always grouped together. The parallel splits and box-like structures represented incompatible distance signals that could not be expressed by a single strictly bifurcating topology. However, the network alone did not allow the biological or methodological causes of these conflicting signals to be distinguished and should not be interpreted as direct evidence of reticulate evolution or hybridization [36,37].

The TCS analysis of the selected Eurasian ITS sequences provided a more direct representation of identical and closely related ITS sequence variants. Sequences assigned to different morphologically identified species frequently shared the same haplotypes, while other haplotypes representing different species

were separated by only a small number of mutational steps. Most sequences generated in this study occurred in the densely connected part of the network together with reference sequences representing several different Eurasian species. The two newly generated sequences of *A. mollis* shared a haplotype that differed by one mutational step from a haplotype containing GenBank-derived *A. mollis* sequences and sequences assigned to other Eurasian taxa. Their proximity to reference sequences of the same species therefore did not constitute an exclusive molecular signature for *A. mollis*. Thus, the sharing of haplotypes among morphologically identified species and the short mutational distances among many remaining variants were consistent with the limited species-level resolution observed in the ITS tree and NeighborNet network. Comparable non-exclusive haplotype patterns have been reported in other taxonomically complex Rosaceae groups affected by apomixis, polyploidy, hybridization or introgression, including *Rubus* and *Rosa* [38,39].

The limited correspondence among morphological species identification, leaf-character variation and ITS differentiation should be considered in the context of the taxonomic complexity of *Alchemilla*, in which apomixis, polyploidy and reticulate evolution may contribute to morphological and genetic overlap among taxa. Apomixis may maintain morphologically recognizable lineages without the genetic differentiation expected under strictly sexual divergence, whereas polyploidy and occasional hybridization may combine genetic material derived from different evolutionary lineages. Recent divergence and incomplete lineage sorting may additionally result in the retention of shared ancestral ITS variants among morphologically differentiated taxa. The incompatible splits observed in the NeighborNet network are compatible with some of these processes, but they do not provide direct evidence that hybridization or reticulate evolution occurred among the investigated plants. Similar processes have been discussed in other polyploid and apomictic plant groups [16,17,19].

The limited species-level resolution may also reflect properties of the ITS marker itself. ITS belongs to a multicopy nuclear ribosomal DNA array and is subject to concerted evolution, which may homogenize sequence variants within a genome while obscuring contributions inherited from different parental lineages [40,41]. Conversely, incomplete homogenization may produce intragenomic ITS variation, particularly in hybrid and polyploid taxa [40,41]. Because direct Sanger sequencing generally represents the predominant consensus sequence, the present analysis could not characterize the full range of ITS variants occurring within individual genomes [42,41]. Consequently, the absence of species-exclusive ITS lineages or haplotypes may reflect both the evolutionary history of the examined taxa and the limited ability of consensus ITS sequences

to represent their genomic complexity. The relative contributions of these processes cannot be determined from the present data.

The flow cytometric analysis of 16 samples representing eight *Alchemilla* taxa collected at different localities in Poland provided insight into variation in 2C nuclear DNA content. The 2C values ranged from 3.52 to 3.72 pg, and the maximum difference between samples was approximately 5.7%. Statistically significant differences were detected only between *A. hirsuticaulis* from Krokowa, which had the lowest value, and the two *A. glaucescens* samples from Rąb and Osowa, which had the highest values, whereas all remaining samples formed a broadly overlapping intermediate group. The limited genome size differentiation among morphologically distinct taxa should be interpreted in the context of the biology of the genus, which is characterized by interspecific hybridization, apomixis and high morphological variability that complicate its taxonomy [3].

The estimates obtained in the present study are consistent with published data for the genus. For the flora of the Netherlands, a mean 2C value of about 3.73 pg was reported for *Alchemilla*, ranging from 3.56 to 3.89 pg across 35 measurements of 12 species. 2C DNA values of 3.71 pg for *A. mollis* and 3.79 pg for *A. glabra*, with chromosome numbers of approximately 2n = 96-110, were also reported [43]. For *A. plicata*, a 2C value of 3.69 pg was reported by Loureiro et al. [44], and the same value was obtained in the present study for *A. subcrenata* and for *A. mollis* from Chrząstawa Mała. Lower 2C values of 3.23 pg for *A. glabra* and 3.35 pg for *A. monticola*, both assigned to the 14x ploidy level, were reported by Šmarda et al. [45]. These values are 6-11% lower than those obtained here for the same species (3.56-3.63 pg and 3.58 pg, respectively) and are also lower than the value reported for *A. glabra* by Zonneveld [43]. Similarly, a 2C value of 3.30 pg was reported for *A. xanthochlora* by Šmarda et al. [45], whereas 3.53 pg was obtained for this species by Pustahija et al. [46]. The consistently lower values reported by Šmarda et al. [45], all obtained using *Glycine max* 'Polanka' as the internal standard, may therefore reflect a methodological offset, e.g., related to the choice of the reference standard or staining protocol, rather than true biological divergence [47].

Intraspecific variation in genome size was small, and 2C DNA values ranged from 3.63 to 3.72 pg in *A. glaucescens*, from 3.56 to 3.63 pg in *A. glabra*, from 3.60 to 3.67 pg in *A. gracilis*, and from 3.58 to 3.69 pg in *A. mollis*. None of these intraspecific differences was significant. This is consistent with the view that nuclear DNA content is fairly constant within a single evolutionary entity [48]. However, high standard deviations were recorded for two accessions: *A. glaucescens* from Gile (SD = 0.43 pg) and *A. mollis* from Chrząstawa Mała (SD = 0.31 pg). This may indicate the co-occurrence of different cytotypes or aneuploid variants within these populations, which should be verified by chromosome counts. According to the genome size

categories defined by Soltis et al. [49], all investigated *Alchemilla* samples possess small genomes. To the best of our knowledge, nuclear DNA content is reported here for the first time for five taxa: *A. glaucescens*, *A. subcrenata*, *A. gracilis*, *A. subglobosa* and *A. hirsuticaulis*.

Taken together, the three analytical approaches revealed variation at different levels but did not provide consistently concordant patterns of species-level differentiation. The SEM observations documented recurrent leaf-surface variation, although none of the recorded character states or three operational combinations was restricted to a single morphologically identified species. Similarly, the molecular analyses did not consistently recover species-exclusive lineages or ITS sequence variants, whereas the flow cytometric estimates showed extensive overlap in nuclear DNA content among most of the examined taxa. These results should not be interpreted as evidence that the recognized taxa lack biological differentiation or that the observed leaf variation is exclusively environmentally determined. Rather, they indicate that none of the examined character systems or molecular markers is sufficient on its own for unambiguous discrimination of the focal species. The datasets should therefore be regarded as complementary sources of evidence describing different aspects of variation within this taxonomically complex group [27-29].

Several limitations define the scope of the conclusions that can be drawn from the present study. Sampling was unequal among species, and taxa represented by only one or two SEM samples did not permit reliable assessment of within-species stability in the recorded leaf characters. Moreover, several SEM characters were evaluated qualitatively, the available images were not obtained using fully standardized magnifications and fields of view, and no quantitative morphometric measurements were performed. Consequently, comparisons of leaf-surface variation should be interpreted primarily at the species level. Molecular sampling was also uneven among markers and taxa: no ITS sequence was obtained for *A. monticola*, whereas *A. hirsuticaulis* and *A. subglobosa* were each represented by only one newly generated ITS sequence, preventing an equivalent assessment of species-level resolution across all focal taxa. The molecular datasets additionally differed in sequence number, taxonomic coverage, alignment length and missing-data content. The geographic representation of GenBank-derived sequences was uneven, and the accuracy of some public species identifications could not be independently verified; therefore, the broad geographic structure recovered in the ITS analyses should not be interpreted as a formal biogeographic reconstruction. Direct Sanger sequencing also provided consensus ITS sequences and did not capture possible intragenomic variation in multicopy ribosomal DNA.

Further evaluation of species boundaries in European *Alchemilla* will require denser and more balanced sampling of multiple individuals from several populations per species, combined with independent verification of morphological identifications, chromosome counts, replicated genome-size estimates, standardized leaf morphometrics, and higher-resolution genomic data such as target-enrichment datasets or genome-wide SNP approaches. Common-garden experiments or replicated sampling across contrasting environmental conditions would additionally help distinguish stable morphological differences from environmentally induced variation. Such an integrative approach could clarify the extent of genetic differentiation among morphologically recognized microspecies and determine how apomixis, polyploidy, hybridization and phenotypic plasticity jointly contribute to the observed patterns of variation.

4. Materials and Methods

4.1. Plant material and sampling

The study included 49 specimens representing eight morphologically identified species of the genus *Alchemilla* L., collected from 17 sampling sites distributed across Poland, namely: *A. glabra* Neygenf., *A. glaucescens* Wallr., *A. gracilis* Opiz, *A. hirsuticaulis* H. Lindb., *A. mollis* (Buser) Rothm., *A. monticola* Opiz, *A. subcrenata* Buser, and *A. subglobosa* C.G. Westerl. The sampled individuals originated from both lowland and montane localities. Each plant was identified using on the taxonomic keys of Rutkowski [11], Szafer et al. [50], and Pawłowski [51]. Representative voucher specimens documenting the sampled populations were deposited in the UGDA Herbarium. Because more than one individually coded plant was collected from some populations, multiple individual codes may be linked to the same population-level voucher. Detailed information on the individually coded samples used for DNA sequencing, including individual sample codes, species identification, sampling localities, geographic coordinates, voucher numbers, and GenBank accession numbers, is provided in Table S5. SEM samples and image-set identifiers are listed in Table S2, whereas the material included in the flow cytometric analyses is summarized in Table S7. Because material availability and quality differed among individuals, not every sampled plants yielded usable data for all analyses.

4.2. Scanning Electron Microscopy

Mature, fully expanded leaves were selected for SEM analyses to minimize the influence of ontogenetic variation. Small fragments were excised from the apical region of the leaf blades,

and adaxial and abaxial surfaces were examined where suitable material and SEM images were available. Because the availability and quality of material differed among individuals, SEM observations were available for 27 separately collected leaf samples representing individual plants. Detailed information on the material used for SEM analyses is provided in Table S2.

Fresh leaf fragments were fixed for 24 h at room temperature in 2.5% (w/v) paraformaldehyde (PFA) and 2.5% (v/v) glutaraldehyde (GA) in 0.1 M cacodylate buffer. The material was subsequently washed twice in 0.1 M cacodylate buffer for 15 min at room temperature and dehydrated through a graded ethanol series. Samples were dried with liquid CO_2 using an Emitech Critical Point Dryer K850 (Emitech Ltd., Ashford, Kent, UK). The dried material was mounted on SEM stubs and sputter-coated with an approximately 10 nm layer of gold using an SPI-Module Sputter Coater (Structure Probe, Inc., West Chester, PA, USA). All preparations were observed and photographed using a Philips XL-30 scanning electron microscope (Philips Electron Optics, Eindhoven, The Netherlands) operated at an accelerating voltage of 15 kV and equipped with a secondary electron detector.

Both adaxial and abaxial leaf surfaces were examined where suitable SEM images were available, with particular attention to the relative size of the apical tooth compared with the two adjacent marginal teeth, trichome abundance, distribution and external morphology, epidermal cell shape, anticlinal wall outline, stomatal morphology and qualitative distribution, subsidiary cell differentiation, and epicuticular wax deposition. The relative size of the apical tooth was assessed qualitatively from low-magnification SEM images and classified into two observed character states: smaller than or larger than the adjacent marginal teeth. No direct morphometric measurements were performed. Trichome abundance was categorized qualitatively as sparse or dense indumentum according to the operational criteria specified in Table S1. Trichomes were classified as cylindrical unicellular or clavate-cylindrical multicellular, with multicellularity assessed on the basis of clearly visible cell boundaries rather than superficial segmentation. Variation in the number of constituent cells in multicellular trichomes was recorded descriptively but was not used to define additional trichome categories [21,52].

Qualitative assessments of apical-tooth size, trichome abundance, stomatal distribution, and epicuticular wax abundance were made using the operational criteria specified in Table S1. Because SEM images were not obtained under fully standardized magnification and field-of-view conditions, stomatal abundance and distribution were treated qualitatively and were not subjected to quantitative comparison among samples. Observations that could not be assessed reliably because of sample orientation or insufficient image coverage or quality were recorded as missing data rather than inferred from

incomplete observations. The SEM analysis was descriptive and exploratory. The qualitative character states were used to summarize recurrent patterns among the examined samples and to assess their potential taxonomic relevance rather than to establish a formal species-delimitation framework.

4.3. Flow Cytometry and Genome Size Estimation

Genome size was estimated in young leaves of all *Alchemilla* populations. Samples for flow cytometric analysis were prepared according to the protocol described by Rewers and Jędrzejczyk [53]. Plant material was chopped with a sharp razor blade in a Petri dish containing 1 mL of nuclei isolation buffer (0.1 M Tris, 2.5 mM $MgCl_2 \cdot 6H_2O$, 85 mM NaCl, 0.1% (v/v) Triton X-100), supplemented with propidium iodide (PI; 50 μg/mL), ribonuclease A (RNase A; 50 μg/mL), and 1.0% (w/v) polyvinylpyrrolidone (PVP-10). Leaves of Solanum lycopersicum 'Stupické' (2C = 1.96 pg; [54]) were used as an internal standard. The chopped plant material was filtered through a 50-μm nylon mesh. For each sample, fluorescence was measured in 5,000-7,000 nuclei using a CyFlow Ploidy Analyzer flow cytometer (Sysmex Partec GmbH, Münster, Germany) with linear signal amplification. Histograms were analyzed using CyView 1.6 software (Sysmex Partec GmbH). Nuclear DNA content was calculated using the linear relationship between the ratio of the 2C peak positions of the *Alchemilla* genotypes and the internal standard in the fluorescence intensity histograms. Raw flow cytometric data are provided in Table S3. The mean coefficient of variation (CV) of the G0/G1 peak of *Alchemilla* species ranged between 4.40 and 6.11% (Table S7). The 2C DNA contents (pg) were converted to megabase pairs using the conversion 1 pg = 978 Mbp [47]. The results were statistically analyzed using one-way analysis of variance (ANOVA) followed by the Newman-Keuls test (P = 0.05; Statistica v. 13.3, StatSoft, Poland). Summary results of the flow cytometric analyses are provided in Table S7.

4.4. DNA Extraction, Amplification and Sequencing

Leaf fragments (20-22 mg) previously dried in silica gel [55] were used for DNA isolation. Tissue homogenization was performed using a FastPrep homogenizer with a ceramic bead and laboratory sand. Genomic DNA was subsequently extracted using the Sherlock AX kit (A&A Biotechnology, Poland) according to the manufacturer's protocol, with minor modifications. During the lysis step, samples were incubated for 4 h at 55°C in the presence of 30 μL of Proteinase K. The resulting DNA pellet was resuspended in 50 μL of TE buffer. DNA concentration (ng/μL) and purity (A260/A280) were determined using a NanoDrop One spectrophotometer (Thermo Scientific, Waltham, MA, USA).

Both amplification and sequencing reactions were carried out using the same primer pairs. For the nrDNA (ITS1-5.8S-ITS2) region, primers ITS_17SE-F and ITS_26SE-R [56] were used; for a partial region of the *matK* gene, primers *matK3-F* and *matK4-R* [57] were used; for *rpoC1*, primers *rpoC1-F* and *rpoC4-R* were used [58]; and for *trnH-psbA* intergenic spacer, primers *trnH-F* [59] and *psbA-R* [60].

PCR reactions were prepared in a total volume of 25 μL, containing 1 μL of template DNA (~10-100 ng), 1 μL of each primer (10 μM), 12.5 μL of Hot-Start PCR Mix-Start Warm (A&A Biotechnology, Poland), and nuclease-free water. The nrDNA region and the plastid *trnH-psbA* spacer were amplified using the same PCR parameters: 95°C for 5 min; 28 cycles of 95°C for 30 s, 55°C for 30 s, and 72°C for 90 s; and 72°C for 7 min [61]. Amplification of *matK* was performed at 95°C for 1 min; 40 cycles of 95°C for 30 s, 55°C for 60 s, and 72°C for 120 s; and 72°C for 7 min. For *rpoC1*, the PCR profile was 94°C for 3 min; 34 cycles of 94°C for 30 s, 50°C for 30 s, and 72°C for 120 s; and 72°C for 5 min [62].

All PCR products were verified by electrophoresis on a 1% agarose gel at 120 V for 30 min and subsequently purified using the Clean-Up Concentrator kit (A&A Biotechnology, Poland) following the manufacturer's instructions. Final elution was performed in 30 μL of TE buffer. In the next step, purified PCR products were prepared for sequencing (5 μL of purified product and 5 μL of each primer) and submitted to Macrogen (Seoul, South Korea) for sequencing. DNA chromatograms obtained for the analyzed samples were visually inspected, trimmed to remove low-quality terminal regions, and checked for ambiguous base calls using FinchTV v.1.4.0. software (Geospiza, Inc., Seattle, WA, USA). The newly generated sequences were deposited in GenBank under the accession numbers listed in Table S5.

4.5. Phylogenetic analyses

Comarum palustre was selected as the outgroup based on its phylogenetic position within Rosoideae Arn. reported in previous molecular studies [63]. Other sequences representing species of *Alchemilla* were retrieved from GenBank (https://www.ncbi.nlm.nih.gov/genbank/) and included as reference material. Reference sequences were selected to represent the major geographic and phylogenetic lineages of the genus, with denser sampling of Eurasian taxa relevant to the species examined in this study. The complete list of reference sequences, including taxon names, GenBank accession numbers and sources, is provided in Table S4.

Sequence alignments were generated using MAFFT v7 [64] with the E-INS-i strategy and 1,000 iterative refinement cycles. The resulting alignments were automatically trimmed using trimAl v1.4 [65] with the "automated1" option to remove

ambiguously aligned positions prior to further analyses. After alignment trimming, terminal gaps resulting solely from differences in sequence length were replaced with the ambiguity character “N”, because these positions represented unavailable sequence information rather than inferred insertion-deletion events. Thus, terminal gaps were treated as unknown nucleotides rather than as phylogenetically informative gaps.

As an initial exploration of sequence variation among the analysed markers, several descriptive parameters were calculated for each dataset, including the number of variable sites, parsimony-informative sites, nucleotide diversity (π), and the proportion of missing data (classified as “N”). These parameters were used to characterize sequence variability and data completeness among the analysed regions. All statistics were calculated in RStudio (v. 2024.04.1 "Chocolate Cosmos") using the ‘ape’ v. 5.8-1 [66], ‘phangorn’ v. 2.12.1 [67], and ‘seqinr’ v. 4.2-44 [68] packages.

Phylogenetic analyses were subsequently performed separately for each dataset using both maximum likelihood (ML) and Bayesian inference (BI) to assess phylogenetic structure, compare the resulting topologies and evaluate node support using transfer bootstrap expectation (TBE) values and Bayesian posterior probabilities (PP), respectively. Bayesian inference was implemented in MrBayes v. 3.2.7 [69] via the CIPRES Science Gateway [70]. The best-fitting evolutionary models were calculated using the following website http://www.atgc-montpellier.fr and based on the Akaike Information Criterion (AIC). The GTR+I+G was selected for ITS region, and for plastid datasets the following F81+I+G for part *matK* gene, GTR+G for *rpoC1*, and HKY+G for *trnH-psbA*. Two parallel MCMC runs were conducted for 6 million generations for the ITS marker and 5 million generations for the remaining markers, with sampling every 1,000 generations. The runs were continued until the average standard deviation of split frequencies fell below 0.01. The first 25% of trees were discarded as burn-in. Maximum Likelihood analyses were conducted in RAxML GUI 2.0 [71]. Branch support was assessed using 1,000 bootstrap replicates, and support values were summarized using the Transfer Bootstrap Expectation (TBE) metric.

Because the ITS marker provided the highest level of phylogenetic informativeness and the most comprehensive taxon sampling, the corresponding phylogenetic tree is presented in the main text. The topologies obtained from Bayesian Inference (BI) and Maximum Likelihood (ML) analyses were largely congruent, with no conflicting relationships receiving strong support in both analyses (BS ≥ 75 i PP ≥ 0.95). Therefore, the ML tree is presented, with node support indicated by ML bootstrap percentages and Bayesian posterior probabilities for corresponding nodes. Trees reconstructed separately for the

plastid markers *matK*, *rpoC1*, and *trnH-psbA* are provided as Supplementary Figures S2-S4.

4.6. Phylogenetic network and haplotype analyses

A split network based on ITS sequences was constructed using the NeighborNet method [36] implemented in the SplitsTree App v. 6.4.7 [72]. The analysis was performed using uncorrected p-distances and was intended to complement the Maximum Likelihood and Bayesian phylogenetic analyses by providing an alternative visualization of relationships among the analysed *Alchemilla* sequences. In particular, NeighborNet was used to visualize potentially conflicting distance signals and non-tree-like patterns that may not be fully represented by bifurcating phylogenetic trees. The outgroup sequence of *Comarum palustre* was excluded from this analysis, and the resulting network was treated as unrooted. The analysis therefore included 216 *Alchemilla* ITS sequences, comprising 40 sequences generated in the present study and 176 reference sequences retrieved from GenBank. For graphical presentation, specific epithets were abbreviated to five letters and combined with either the individual AKC code of the corresponding individually sampled plant or the corresponding GenBank accession number for reference sequences. The graphical layout was subsequently adjusted in Inkscape v. 1.4 [73] to improve label arrangement and figure readability without modifying the network structure or branch lengths.

Based on the structure revealed by the NeighborNet analysis, an additional haplotype network was constructed for a selected subset of 81 ITS sequences representing 41 Eurasian taxa. This subset was selected because it contained the sequences most directly comparable with the material analysed in the present study and was therefore considered the most relevant for a more detailed examination of relationships among closely related sequences and individually sampled plants. The haplotype network was inferred using the TCS statistical parsimony method [74] implemented in PopART [75]. Identical aligned ITS consensus sequences were collapsed into shared haplotypes, whereas connections between haplotypes represented mutational differences among sequence variants. No outgroup was included in this analysis, and the network was interpreted as unrooted. The final graphical presentation was adjusted in Inkscape (v. 1.4) [73] without altering the inferred haplotype relationships or the number of mutational steps. The complete list of ITS sequences included in the network analyses, together with full taxon names, sequence labels, sources, and GenBank accession numbers, is provided in Table S6.

5. Conclusions

SEM examination of the leaf surface revealed substantial variation in the relative size of the apical tooth and in trichome abundance and distribution, whereas epidermal, stomatal, and epicuticular wax characters did not form consistent species-specific patterns. Three operational leaf-character combinations were distinguished based on the relative size of the apical tooth and trichome abundance, but none was restricted to a single morphologically identified species. Consequently, within the examined material, the recorded leaf characters were not sufficiently diagnostic for independent species identification, although they may contribute to a multicharacter taxonomic approach.

The investigated *Alchemilla* samples showed a narrow range of 2C nuclear DNA content, corresponding to small genomes. Statistically significant differences were detected only between *A. hirsuticaulis* from Krokowa and the two *A. glaucescens* samples from Rąb and Osowa, whereas the remaining estimates overlapped extensively among taxa. Thus, nuclear DNA content did not provide clear species-level discrimination within the examined material. The results were generally consistent with previously published data, and nuclear DNA content is reported here for the first time for five taxa. Future taxonomic studies of *Alchemilla* may benefit from integrating genome size estimates with chromosome counts and molecular markers.

Among the molecular markers examined, ITS contained the highest proportion of variable and parsimony-informative sites and recovered broad-scale phylogenetic structure corresponding partly to the geographic origins of the included sequences. However, the phylogenetic and network analyses did not consistently recover species-specific groups among the focal European taxa, indicating that ITS did not provide unambiguous species identification within the examined material. The plastid markers *matK*, *rpoC1*, and *trnH-psbA* likewise showed limited discriminatory power. Although *matK* contained the greatest number of variable sites among the plastid alignments, none of the plastid datasets consistently resolved the investigated species.

The limited correspondence between morphological identification and molecular differentiation may be associated with apomixis, polyploidy, hybridization and the concerted evolution of multicopy nrDNA, although these processes were not directly tested in the present study. Overall, the complementary examination of leaf micromorphology, molecular markers, and flow cytometry revealed substantial variation within the examined material, yet none of these approaches, when considered independently, showed a consistent and unambiguous correspondence with morphological species identification. These results highlight the need for integrative taxonomic research

in European *Alchemilla,* while the observed lack of congruence should not itself be interpreted as evidence against the biological differentiation of the recognized taxa. Future studies should combine denser and more balanced population sampling, cytogenetic analyses, standardized morphometrics, and high-resolution genomic datasets assess the extent of differentiation among morphologically recognized microspecies and clarify the processes responsible for the discordance among datasets.

Supplementary Materials: The following supporting information can be downloaded at: Figure S1: maximum-likelihood phylogeny of *Alchemilla* inferred from the ITS dataset. Values at nodes represent bootstrap support (BS) and Bayesian posterior probabilities (PP), respectively, Figure S2: maximum-likelihood phylogeny of *Alchemilla* inferred from the *matK* dataset. Values at nodes represent bootstrap support (BS) and Bayesian posterior probabilities (PP), respectively, Figure S3: maximum-likelihood phylogeny of *Alchemilla* inferred from the *rpoC1* dataset. Values at nodes represent bootstrap support (BS) and Bayesian posterior probabilities (PP), respectively, Figure S4: maximum-likelihood phylogeny of *Alchemilla* inferred from the *trnH-psbA* dataset. Values at nodes represent bootstrap support (BS) and Bayesian posterior probabilities (PP), respectively; Table S1: operational definitions of leaf micromorphological characters used in SEM analyses, Table S2: SEM-based leaf micromorphological characteristics of the investigated *Alchemilla* L. (Rosaceae) specimens, Table S3: nuclear DNA content of the investigated Alchemilla accessions, Table S4: identification of sequence labels used in the *matK*, *rpoC1* and *trnH-psbA* analyses, Table S5: molecular herbarium specimen of *Alchemilla* L. (Rosaceae), Table S6: identification of sequence labels used in the ITS NeighborNet network, Table S7: genome size of the investigated *Alchemilla* accessions, Table S8: collapsed species and their geographic distributions based on the ITS phylogeny.

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Abbreviations

The following abbreviations are used in this manuscript:

DNA	Deoxyribonucleic Acid
ITS	Internal Transcribed Spacer
nrDNA	nuclear ribosomal DNA
SEM	Scanning Electron Microscopy
ML	Maximum Likelihood
BS	Bootstrap Support
PP	Posterior Probability
TCS	Statistical parsimony method
SD	Standard Deviation
SNP	Single-Nucleotide Polymorphism
PFA	Paraformaldehyde
GA	Glutaraldehyde
PI	Propidium Iodide
RNase	Ribonuclease
PVP	Polyvinylpyrrolidone
CV	Coefficient of Variation
TE	Tris-EDTA buffer
PCR	Polymerase Chain Reaction
MAFFT	Multiple Alignment using Fast Fourier Transform
BI	Bayesian Inference
TBE	Transfer Bootstrap Expectation
CIPRES	Cyberinfrastructure for Phylogenetic Research
AIC	Akaike Information Criterion
GTR	General Time Reversible model
HKY	Hasegawa-Kishino-Yano model
MCMC	Markov Chain Monte Carlo
GUI	Graphical User Interface

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Supplementary Table S1. Operational definitions of leaf micromorphological characters used in SEM analyses

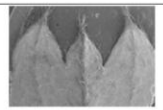
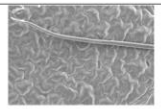
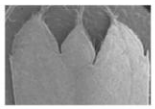
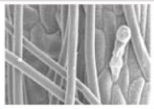
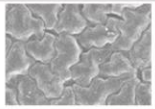
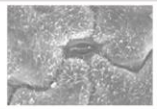
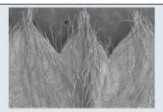
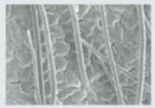
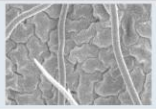
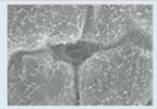
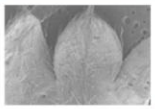
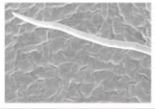
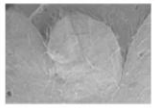
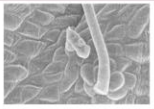
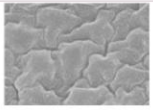
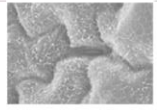
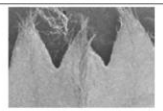
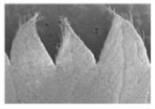
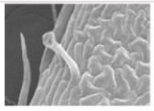
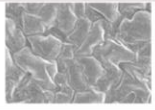
Supplementary Table S1. Operational definitions of leaf micromorphological characters used in SEM analyses

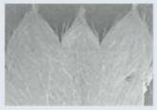
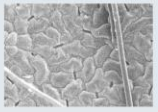
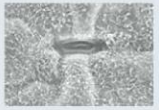
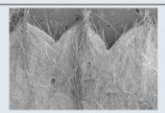
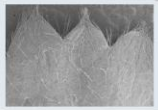
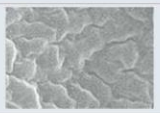
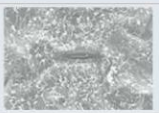
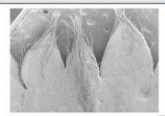
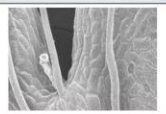
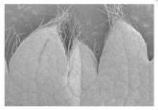
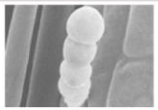
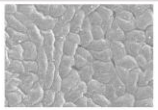
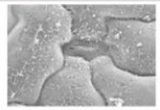
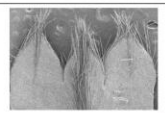
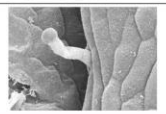
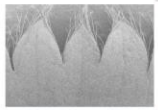
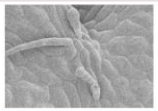
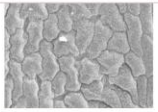
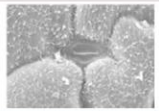
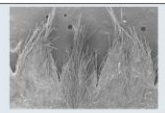
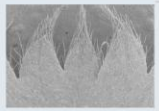
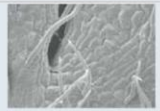
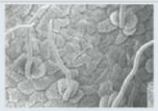
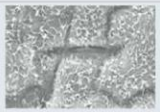
Character	State / term used	Operational definition used in this study
Relative size of the apical tooth	smaller	Apical tooth visibly smaller than the adjacent marginal teeth in low-magnification SEM images; assessed qualitatively by visual comparison rather than direct measurement.
Relative size of the apical tooth	larger	Apical tooth visibly larger than the adjacent marginal teeth in low-magnification SEM images; assessed qualitatively by visual comparison rather than direct measurement.
Trichome abundance (indumentum)	sparse	Relatively low trichome abundance within the examined leaf fragment; trichomes do not form an extensive continuous cover, even when distributed across the lamina.
Trichome abundance (indumentum)	dense	Numerous trichomes forming an extensive cover within the examined leaf fragment.
Trichome distribution	predominantly along veins and/or margins	Trichomes restricted mainly to the leaf veins and/or margins, with little or no trichome cover across most of the lamina.
Trichome distribution	distributed across the lamina	Trichomes present across the lamina in addition to the veins and/or margins; local differences in density may occur.
Trichome morphology	cylindrical unicellular	Simple trichome composed of a single elongated cylindrical cell.
Trichome morphology	clavate-cylindrical multicellular	Multicellular trichome with an elongated clavate-cylindrical outline and clearly visible constituent cell boundaries.
Cell number in multicellular trichomes	2–8 cells (descriptive only)	Number of clearly visible constituent cells; recorded as within-category variation and not used to define additional trichome morphotypes.
Epidermal cell shape	irregularly polygonal	Epidermal cells polygonal in general outline but variable in size and shape.
Epidermal cell shape	irregularly polygonal to subisodiametric	Epidermal cells ranging from irregularly polygonal to approximately equal in length and width.
Epidermal cell shape	irregularly polygonal to elongate-polygonal	Epidermal cells showing a continuum between irregularly polygonal and distinctly elongated polygonal outlines; the reverse term order used for one S2 sample represents the
Anticlinal wall outline	straight to slightly sinuate	Anticlinal walls straight or showing only shallow, weakly expressed undulations.
Anticlinal wall outline	slightly sinuate	Anticlinal walls showing shallow and weakly expressed undulations.
Anticlinal wall outline	slightly to moderately sinuate	Anticlinal walls intermediate between slightly and moderately sinuate states.
Anticlinal wall outline	moderately sinuate	Anticlinal walls showing clearly visible and regularly occurring undulations.
Anticlinal wall outline	moderately to distinctly sinuate	Anticlinal walls intermediate between moderately and distinctly sinuate states.
Anticlinal wall outline	distinctly sinuate	Anticlinal walls showing pronounced and frequent undulations.
Stomatal morphology	narrowly elliptic	Stomatal complex distinctly longer than wide, with smoothly rounded ends.
Stomatal morphology	elliptic to narrowly elliptic	Stomatal complexes ranging from elliptic to distinctly elongated, narrowly elliptic outlines.
Stomatal abundance	sparse	Relatively few stomata visible within the examined epidermal area; stomata may be infrequent and separated by larger areas without visible stomata.
Stomatal abundance	numerous	Stomata frequent within the examined epidermal area.
Stomatal distribution	clustered	Stomata locally aggregated into distinct groups or clusters; this distribution state was recorded independently of stomatal abundance.
Stomatal distribution	irregularly distributed	Stomata scattered without a clear or regular spatial pattern.
Stomatal distribution	densely / evenly distributed	Stomata broadly distributed over the examined epidermal surface, with relatively short inter stomatal distances and/or no pronounced clustering.
Subsidiary cell differentiation	weakly differentiated	Subsidiary cells distinguishable only subtly from surrounding epidermal cells by shape, size, or surface appearance.
Subsidiary cell differentiation	not distinctly differentiated	Subsidiary cells not clearly distinguishable from surrounding epidermal cells.
Epicuticular wax abundance	scarce	Limited wax deposits present, usually near stomatal complexes, with most of the surrounding epidermal surface exposed.
Epicuticular wax abundance	moderate	Wax deposits clearly present but discontinuous, leaving a substantial part of the surrounding epidermal surface exposed.
Epicuticular wax abundance	abundant	Extensive wax deposits present around stomatal complexes and adjacent epidermal cells, commonly forming a dense reticulate coating.
Epicuticular wax abundance	very abundant	Dense and extensive wax deposits covering or obscuring most of the epidermal surface surrounding stomatal complexes.
Epicuticular wax distribution	restricted / concentrated around the stomatal complex and adjacent cells	Wax deposits restricted to, concentrated around, or sparsely distributed in the vicinity of stomatal complexes, subsidiary cells, and/or adjacent epidermal cells.
Epicuticular wax distribution	extending onto the surrounding epidermal surface	Wax deposits extending beyond the stomatal region onto adjacent epidermal cells.
Epicuticular wax pattern	reticulate	Wax deposits forming a net-like arrangement on the examined epidermal surface.
Epicuticular wax pattern	discontinuous reticulate	Reticulate wax pattern interrupted by areas in which the epidermal surface remains exposed.
Epicuticular wax pattern	dense / extensive reticulate network	Strongly developed reticulate wax deposits covering a substantial part of the surrounding epidermal surface.
Operational leaf-character combination	Type I	Apical tooth smaller than the adjacent marginal teeth combined with sparse indumentum.
Operational leaf-character combination	Type II	Apical tooth smaller than the adjacent marginal teeth combined with dense indumentum.
Operational leaf-character combination	Type III	Apical tooth larger than the adjacent marginal teeth combined with dense indumentum.

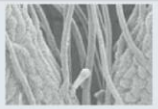
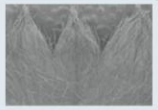
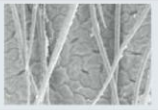
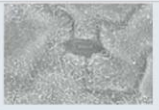
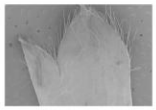
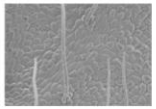
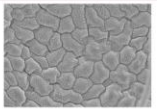
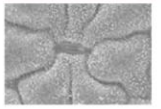
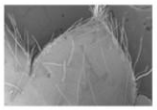
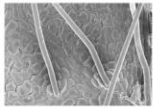
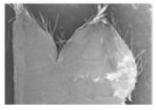
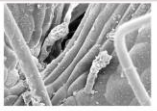
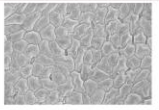
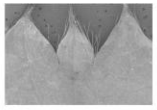
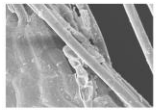
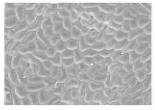
Note: No examined SEM sample combined an apical tooth larger than the adjacent marginal teeth with sparse indumentum. Trichome abundance and distribution, stomatal abundance and distribution, and epicuticular wax abundance, distribution, and pattern were treated as separate descriptive attributes. Missing or unassessable observations were recorded as missing data rather than inferred from incomplete images.

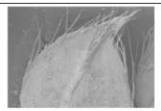
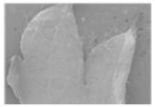
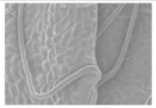
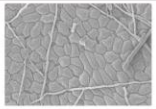
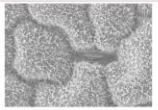
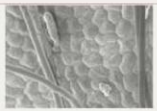
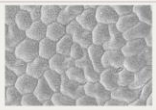
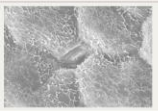
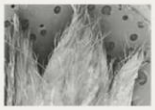
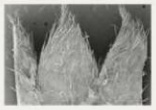
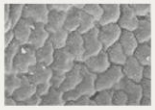
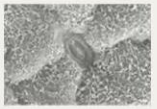
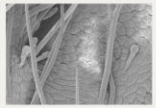
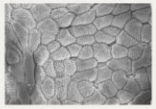
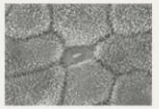
Supplementary Table S2. SEM-based leaf micromorphological characteristics of the investigated *Alchemilla* L. (Rosaceae) specimens.

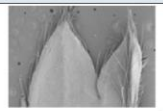
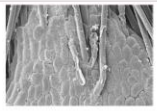
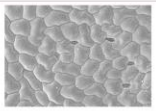
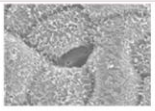
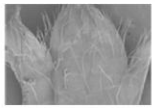
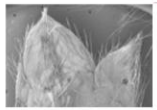
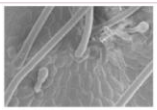
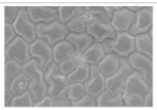
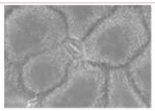
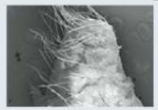
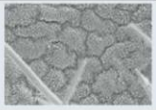
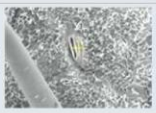
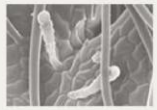
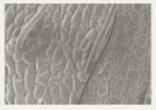
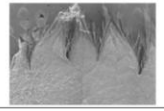
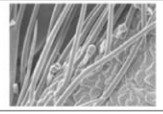
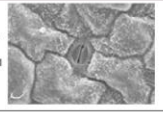
Supplementary Table S2. SEM-based leaf micromorphological characteristics of the investigated *Alchemilla* L. (Rosaceae) specimens.

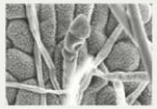
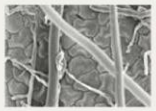
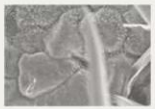
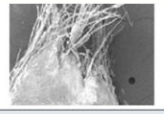
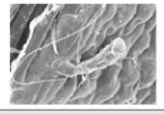
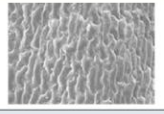
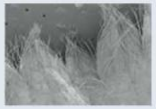
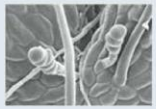
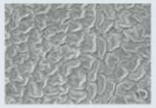
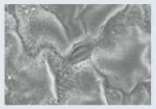
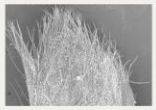
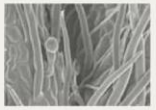
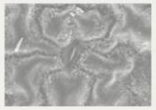
No.	Study no.	Species	Locality	Voucher	Operational leaf-character combination	Apical tooth morphology	Apical tooth morphology – description	Trichome morphology – SEM	Trichome morphology – description	Epidermal cell characteristics – SEM	Epidermal cell characteristics – description	Stomatal characteristics and epicuticular wax – SEM	Stomatal characteristics and epicuticular wax – description
1	1	*Alchemilla glabra* Neygenf.	Przetoczyno area, Szemud Commune, Wejherowo County, Pomeranian Voivodeship, Poland GPS: 54.42769, 18.49034	UGDA.0109006	Type I				Adaxial surface: sparse indumentum, with isolated trichomes distributed across the lamina and a higher density along the leaf margin. Trichome types were identical to those observed on the abaxial surface.				Stomata: narrowly elliptic, numerous and densely distributed; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: sparse indumentum, with trichomes distributed across the lamina and a higher density along the leaf margin, midrib, and lateral veins. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were tricellular.		Abaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls distinctly sinuate.		Epicuticular wax: abundant, concentrated around the stomatal complex and subsidiary cells, forming a dense reticulate coating.
2	2	Alchemilla glabra Neygenf.	Przetoczyno area, Szemud Commune, Wejherowo County, Pomeranian Voivodeship,Poland GPS: 54.42769, 18.49034	UGDA.0109006	Type II				Adaxial surface: dense indumentum distributed across the lamina, with a higher density along the leaf margin. Trichome types were identical to those observed on the abaxial surface.				Stomata: narrowly elliptic, sparse and occurring in small clusters; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: dense indumentum distributed across the lamina, with particularly high density along the leaf margin, midrib, and lateral veins. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were tetracellular.		Abaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls slightly to moderately sinuate.		Epicuticular wax: abundant, concentrated around the stomatal complex and subsidiary cells, forming a dense reticulate network.
3	3	*Alchemilla glaucescens* Wallr.	Rąb, Otałżyńska Street, Przodkowo Commune, Kartuzy County, Pomeranian Voivodeship, Poland GPS: 54.42380, 18.22653	UGDA.0057412	Type I				Adaxial surface: sparse indumentum, with isolated trichomes distributed across the lamina and a higher density along the leaf margin. Cylindrical unicellular trichomes with multicellular basal complexes and rare, short clavate-cylindrical multicellular trichomes were present; the latter were tetracellular.				Stomata: narrowly elliptic, numerous and densely distributed; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: sparse indumentum, with trichomes distributed across the lamina and a higher density along the leaf margin and midrib. Cylindrical unicellular trichomes with multicellular basal complexes and rare clavate-cylindrical multicellular trichomes were present; the latter were tricellular.		Abaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls slightly to moderately sinuate.		Epicuticular wax: moderate, concentrated around the stomatal complex and subsidiary cells, forming a discontinuous reticulate coating.
4	4	*Alchemilla subcrenata* Buser	Mrzezino, south of the village, north of the Reda River, Puck County, Pomeranian Voivodeship, Poland GPS: 54.64437, 18.43296	UGDA.0109003	Type I				Adaxial surface: sparse indumentum, with trichomes restricted to the leaf margin and absent from the central lamina. Cylindrical unicellular and rare, short clavate-cylindrical multicellular trichomes were present; the latter were bicellular.				Stomata: narrowly elliptic, numerous and densely distributed; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: sparse indumentum, with trichomes occurring predominantly along the leaf margin and midrib. Cylindrical unicellular and rare, long clavate-cylindrical multicellular trichomes were present; the latter were bicellular.		Abaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls distinctly sinuate.		Epicuticular wax: scarce, restricted mainly to the vicinity of the stomatal complex and subsidiary cells.

5	5	*Alchemilla glabra* Neygenf.	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland GPS: 54.62009, 18.21020	UGDA.0109002	Type II			Adaxial surface: dense indumentum distributed across the lamina, with a higher density along the leaf margin. Cylindrical unicellular trichomes arising from multicellular basal epidermal complexes and clavate-cylindrical multicellular trichomes were present; the latter were predominantly tetracellular and occasionally tricellular.				Stomata: narrowly elliptic, sparse and occurring in distinct clusters; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: dense indumentum distributed across the lamina, with particularly high density along the leaf margin, midrib, and lateral veins. Cylindrical unicellular trichomes arising from multicellular basal epidermal complexes and clavate-cylindrical multicellular trichomes were present; the latter were tetracellular.		Abaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls slightly to moderately sinuate.		Epicuticular wax: abundant, concentrated around the stomatal complex and subsidiary cells, forming a dense reticulate network.
6	6	*Alchemilla hirsuticaulis* H.Lindb.	Krokowa, Puck County, Pomeranian Voivodeship, Poland GPS: 54.7797, 18.1663	UGDA.0109014	Type II			Adaxial surface: dense indumentum distributed across the lamina, with a higher density along the leaf margin. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were tricellular.				Stomata: narrowly elliptic, sparse and irregularly distributed; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: dense indumentum distributed across the lamina, with particularly high density along the leaf margin, midrib, and lateral veins. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were tricellular.		Abaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls slightly to moderately sinuate.		Epicuticular wax: abundant, concentrated around the stomatal complex and subsidiary cells, forming a dense reticulate coating.
7	7	*Alchemilla glabra* Neygenf.	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland GPS: 54.62009, 18.21020	UGDA.0109002	Type I				Adaxial surface: sparse indumentum, with trichomes restricted to the leaf margin. Trichome types were identical to those observed on the abaxial surface.				Stomata: narrowly elliptic, numerous and densely distributed; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: sparse indumentum, with trichomes occurring predominantly along the leaf margin and midrib. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were tricellular.		Abaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls slightly to moderately sinuate.		Epicuticular wax: scarce, concentrated mainly around the stomatal complex and adjacent subsidiary cells.
8	8	*Alchemilla glabra* Neygenf.	Ustarbowo, Wejherowo Commune, Wejherowo County, Pomeranian Voivodeship, Poland GPS: 54.55825, 18.20728	UGDA.0202306	Type I				Adaxial surface: sparse indumentum, with trichomes restricted to the leaf margin. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were tetra- to pentacellular.				Stomata: narrowly elliptic, numerous and densely distributed; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: sparse indumentum, with trichomes occurring predominantly along the leaf margin and midrib. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were tetracellular.		Abaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls slightly to moderately sinuate.		Epicuticular wax: scarce, sparsely distributed around the stomatal complex and adjacent epidermal cells.
9	9	*Alchemilla mollis* (Buser) Rothm.	Chrząstawa Mała, Czernica Commune, Wrocław County, Lower Silesian Voivodeship, Poland GPS: 51.083, 17.2846	UGDA.0109018	Type II			Adaxial surface: dense indumentum distributed across the lamina, with a higher density along the leaf margin. Only cylindrical unicellular trichomes were observed.				Stomata: narrowly elliptic, sparsely distributed and locally aggregated into clusters; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: dense indumentum distributed across the lamina, with particularly high density along the leaf margin, midrib, and lateral veins. Cylindrical unicellular trichomes arising from multicellular basal epidermal complexes were present.		Abaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls distinctly sinuate.		Epicuticular wax: abundant, concentrated around the stomatal complex and subsidiary cells, forming a dense reticulate network.

10	11	*Alchemilla glaucescens* Wallr.	Kochanowo area, near the Góra Forest District headquarters, Luzino Commune, Wejherowo County, Pomeranian Voivodeship, Poland GPS: 54.615308, 18.110520	UGDA.0109015	Type II			Adaxial surface: dense indumentum distributed across the lamina, with a higher density along the leaf margin. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were tetracellular.					Stomata: narrowly elliptic, sparse and occurring in distinct clusters; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: dense indumentum distributed across the lamina, with particularly high density along the leaf margin, midrib, and lateral veins. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were tetracellular.		Abaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls slightly sinuate.		Epicuticular wax: abundant, concentrated around the stomatal complex and subsidiary cells, forming a dense reticulate coating.
11	12	*Alchemilla glaucescens* Wallr.	Kochanowo area, near the Góra Forest District headquarters, Luzino Commune, Wejherowo County, Pomeranian Voivodeship, Poland GPS: 54.615308, 18.110520	UGDA.0109015	Type II				Adaxial surface: dense indumentum distributed across the entire lamina, with particularly high density along the leaf margin. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were tricellular.				Stomata: narrowly elliptic, sparse and occurring in distinct clusters; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: dense indumentum distributed across the entire lamina, with particularly high density along the leaf margin, midrib, and lateral veins. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were tricellular.		Abaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls slightly to moderately sinuate.		Epicuticular wax: abundant, concentrated around the stomatal complex and subsidiary cells, forming a dense reticulate network.
12	22	*Alchemilla gracilis* Opiz	Wirty, near Arboretum Wirty, Pomeranian Voivodeship, Poland GPS: 53.9011, 18.378	UGDA.0058554	Type I				Adaxial surface: sparse indumentum, with trichomes distributed across the lamina and along the leaf margin. Cylindrical unicellular trichomes arising from multicellular basal epidermal complexes and rare, deformed clavate-cylindrical multicellular trichomes were present; the latter were apparently heptacellular.				Stomata: narrowly elliptic, sparse and irregularly distributed; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: sparse indumentum, with trichomes distributed across the lamina and along the leaf margin. Cylindrical unicellular trichomes arising from multicellular basal epidermal complexes and clavate-cylindrical multicellular trichomes were present; the latter were apparently heptacellular.		Abaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls slightly sinuate.		Epicuticular wax: abundant, concentrated around the stomatal complex and subsidiary cells, forming a dense reticulate network.
13	23	*Alchemilla subcrenata* Buser	Mrzezino, south of the village, north of the Reda River, Puck County, Pomeranian Voivodeship, Poland GPS: 54.64437, 18.43296	UGDA.0109003	Type I				Adaxial surface: sparse indumentum, with trichomes distributed across the lamina and along the leaf margin. Cylindrical unicellular trichomes arising from multicellular basal epidermal complexes and clavate-cylindrical multicellular trichomes were present; the latter were heptacellular.				Stomata: narrowly elliptic, sparse and occurring in distinct clusters; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: sparse indumentum, with isolated trichomes distributed across the lamina and along the leaf margin. Cylindrical unicellular trichomes arising from multicellular basal epidermal complexes were present.		Abaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls moderately sinuate.		Epicuticular wax: abundant, concentrated around the stomatal complex and subsidiary cells, forming a reticulate coating.
14	24	*Alchemilla glabra* Neygenf.	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland GPS: 54.62009, 18.21020	UGDA.0109002	Type I		Apical tooth smaller than the adjacent marginal teeth.		Adaxial surface: sparse indumentum, with trichomes restricted to the leaf margin and absent from the remaining lamina. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were pentacellular. Abaxial surface: not examined (images unavailable).		Adaxial epidermis: epidermal cells irregularly polygonal to subisodiametric; anticlinal walls straight to slightly sinuate.		Stomata: elliptic to narrowly elliptic, sparse and occurring in distinct clusters; subsidiary cells weakly differentiated from surrounding epidermal cells. Epicuticular wax: moderate, concentrated around the stomatal complex and subsidiary cells, forming a discontinuous reticulate coating.

15	25	*Alchemilla glabra* Neygenf.	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland GPS: 54.62009, 18.21020	UGDA.0109002	Type I	 		Adaxial surface: sparse indumentum, with trichomes restricted to the apical portions of the leaf margin. Only cylindrical unicellular trichomes were observed.					Stomata: narrowly elliptic, sparse and occurring in distinct clusters; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: sparse indumentum, with trichomes present along the leaf margin. Only cylindrical unicellular trichomes were observed.		Adaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls slightly sinuate.		Epicuticular wax: abundant, concentrated around the stomatal complex and subsidiary cells, forming a dense reticulate network.
16	27	Alchemilla glaucescens Wallr.	Rąb, Otalżyńska Street, Przodkowo Commune, Kartuzy County, Pomeranian Voivodeship, Poland GPS: 54.42380, 18.22653	UGDA.0057412	Type III	 		Adaxial surface: dense indumentum distributed across the lamina, with a higher density along the leaf margin. Cylindrical unicellular and abundant clavate-cylindrical multicellular trichomes were present; the latter were hexacellular and distributed across the lamina, including its central region.					Stomata: narrowly elliptic, sparse and infrequent; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth larger than the adjacent marginal teeth.		Abaxial surface: dense indumentum distributed across the lamina, with a higher density along the leaf margin. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were hexacellular.		Abaxial epidermis: epidermal cells irregularly polygonal to subisodiametric; anticlinal walls straight to slightly sinuate.		Epicuticular wax: moderate, concentrated around the stomatal complex and subsidiary cells, forming a discontinuous reticulate coating.
17	28	*Alchemilla glabra* Neygenf.	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland GPS: 54.62009, 18.21020	UGDA.0109002	Type III	 		Adaxial surface: dense indumentum distributed across the lamina, with a higher density along the leaf margin. Cylindrical unicellular trichomes arising from multicellular basal epidermal complexes and clavate-cylindrical multicellular trichomes were present; the latter were penta- to hexacellular and distributed throughout the lamina.					Stomata: elliptic to narrowly elliptic, sparse and occurring in distinct clusters; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth larger than the adjacent marginal teeth.		Abaxial surface: dense indumentum distributed across the lamina, with particularly high density along the leaf margin, midrib, and lateral veins. Cylindrical unicellular trichomes arising from multicellular basal epidermal complexes and clavate-cylindrical multicellular trichomes were present; the latter were penta- to hexacellular and distributed throughout the lamina.		Adaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls moderately to distinctly sinuate.		Epicuticular wax: abundant, concentrated around the stomatal complex and subsidiary cells, forming a dense reticulate network.
18	29	*Alchemilla glaucescens* Wallr.	Kochanowo area, near the Góra Forest District headquarters, Luzino Commune, Wejherowo County, Pomeranian Voivodeship, Poland GPS: 54.615308, 18.110520	UGDA.0109015	Type III	 		Adaxial surface: dense indumentum distributed across the lamina, with a higher density along the leaf margin. Cylindrical unicellular trichomes lacking multicellular basal epidermal complexes and clavate-cylindrical multicellular trichomes were present; the latter were hexacellular.					Stomata: elliptic to narrowly elliptic, numerous and densely distributed; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth larger than the adjacent marginal teeth.		Abaxial surface: dense indumentum distributed across the lamina, with particularly high density along the leaf margin, midrib, and lateral veins. Cylindrical unicellular trichomes arising from multicellular basal epidermal complexes and clavate-cylindrical multicellular trichomes were present; the latter were hexacellular and distributed throughout the lamina.		Abaxial epidermis: epidermal cells irregularly polygonal to subisodiametric; anticlinal walls slightly sinuate.		Epicuticular wax: very abundant, densely concentrated around the stomatal complex and subsidiary cells, forming an extensive reticulate network covering most of the surrounding epidermal surface.

19	30	*Alchemilla glabra* Neygenf.	Ustarbowo, Wejherowo Commune, Wejherowo County, Pomeranian Voivodeship, Poland GPS: 54.55825, 18.20728	UGDA.0202306	Type I			Adaxial surface: sparse indumentum, with trichomes restricted to the leaf margin. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were pentacellular.					Stomata: elliptic to narrowly elliptic, sparse and occurring in distinct clusters; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: sparse indumentum, with trichomes concentrated along the leaf margin and midrib, where they were particularly abundant. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were pentacellular.		Adaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls moderately sinuate.		Epicuticular wax: abundant, concentrated around the stomatal complex and subsidiary cells, forming a dense reticulate coating.
20	31	*Alchemilla glaucescens* Wallr.	Osowa district, city of Gdańsk, Pomeranian Voivodeship, Poland GPS: 54.4180515, 18.4423830	UGDA.0202305	Type I			Adaxial surface: sparse indumentum, with trichomes distributed across the lamina and particularly abundant along the leaf margin, midrib, and lateral veins. Cylindrical unicellular and abundant clavate-cylindrical multicellular trichomes were present; the latter were pentacellular and distributed throughout the lamina.					Stomata: narrowly elliptic, sparse and occurring in distinct clusters; subsidiary cells weakly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: sparse indumentum, with trichomes distributed across the lamina and a higher density along the leaf margin. Cylindrical unicellular and abundant clavate-cylindrical multicellular trichomes were present; the latter were pentacellular and distributed throughout the lamina.		Adaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls moderately sinuate.		Epicuticular wax: moderate, concentrated around the stomatal complex and subsidiary cells, forming a discontinuous reticulate coating.
21	32	*Alchemilla mollis* (Buser) Rothm.	Gdańsk-Oliwa, Gdańsk, Pomeranian Voivodeship, Poland (R.O.D. "Leśnik" allotment gardens) GPS: 54.402674, 18.547230	UGDA.0202304	Type II			Adaxial surface: dense indumentum distributed across the lamina, with particularly high density along the leaf margin. Only cylindrical unicellular trichomes were observed.					Stomata: narrowly elliptic, numerous and evenly distributed; subsidiary cells not distinctly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: dense indumentum distributed across the lamina, with particularly high density along the leaf margin, midrib, and lateral veins. Cylindrical unicellular trichomes arising from multicellular basal epidermal complexes were present.		Adaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls moderately sinuate.		Epicuticular wax: very abundant, densely concentrated around the stomatal complex and subsidiary cells, forming an extensive reticulate network that obscures much of the surrounding epidermal surface.
22	33	*Alchemilla glaucescens* Wallr.	Henrykowo, Orneta Commune, Lidzbark County, Warmian-Masurian Voivodeship, Poland GPS: 54.1817, 20.1443	UGDA.0278896	Type III		Apical tooth larger than the adjacent marginal teeth.		Adaxial surface: dense indumentum distributed across the lamina, with particularly high density along the leaf margin. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were heptacellular. Abaxial surface: not examined (images unavailable).		Adaxial epidermis: epidermal cells irregularly polygonal to elongate-polygonal; anticlinal walls slightly sinuate.		Stomata not observed (no suitable SEM images available).
23	34	*Alchemilla monticola* Opiz	Murzasichle vicinity (near Zakopane), Tatra County, Lesser Poland Voivodeship, Poland GPS: 49.3117, 20.0436	UGDA.0202307	Type I			Adaxial surface: sparse indumentum, with trichomes restricted to the leaf margin. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were pentacellular.					Stomata: elliptic to narrowly elliptic, numerous and densely distributed; subsidiary cells not distinctly differentiated from surrounding epidermal cells.
							Apical tooth smaller than the adjacent marginal teeth.		Abaxial surface: sparse indumentum, with trichomes distributed across the lamina and a markedly higher density along the leaf margin. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were pentacellular.		Abaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls obscured by abundant epicuticular wax deposits and fungal hyphae.		Epicuticular wax: abundant, concentrated around the stomatal complex and subsidiary cells, forming a dense reticulate network.

24	35	*Alchemilla monticola* Opiz	Murzasichle vicinity (near Zakopane), Tatra County, Lesser Poland Voivodeship, Poland GPS: 49.3117, 20.0436	UGDA.0202307	Type III				Adaxial surface: dense indumentum distributed across the lamina, with particularly high density along the leaf margin. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were tetra- to pentacellular.				Stomata: not clearly visible; stomatal distribution could not be assessed reliably because of abundant fungal hyphae and trichomes; subsidiary cells not distinctly differentiated from surrounding epidermal cells.
							Apical tooth larger than the adjacent marginal teeth.		Abaxial surface: dense indumentum distributed across the lamina, with particularly high density along the leaf margin, midrib, and lateral veins. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were tetra- to pentacellular.		Adaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls slightly sinuate.		Epicuticular wax: moderate, concentrated around the stomatal complex and adjacent epidermal cells, forming a discontinuous reticulate coating.
25	36	*Alchemilla gracilis* Opiz	Witów, Tatra County, Lesser Poland Voivodeship, Poland GPS: 49.3224, 19.8209	UGDA.0173624	Type I		Apical tooth smaller than the adjacent marginal teeth.		Adaxial surface: sparse indumentum, with trichomes present along the leaf margin. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were hexacellular. Abaxial surface: not examined (images unavailable).		Adaxial epidermis: epidermal cells elongate-polygonal to irregularly polygonal; anticlinal walls distinctly sinuate.		Stomata not observed (no suitable SEM images available).
26	40	*Alchemilla glaucescens* Wallr.	Gile (near Stasiki), Zakopane vicinity, Tatra County, Lesser Poland Voivodeship, Poland GPS: 49.3695, 20.0667	UGDA. 0173599	Type II		Apical tooth smaller than the adjacent marginal teeth.		Adaxial surface: not examined (images unavailable). Abaxial surface: dense indumentum distributed across the lamina, with particularly high density along the leaf margin, midrib, and lateral veins. Cylindrical unicellular and clavate-cylindrical multicellular trichomes were present; the latter were octacellular.		Abaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls distinctly sinuate.		Stomata: elliptic to narrowly elliptic, sparse and occurring in distinct clusters; subsidiary cells not distinctly differentiated from surrounding epidermal cells. Epicuticular wax: scarce, restricted to the vicinity of the stomatal complex and subsidiary cells.
27	41	*Alchemilla subglobosa C.G.Westerl.*	Pokchówko, Krokowa Commune, Puck County, Pomeranian Voivodeship, Poland GPS: 54.72966, 18.20799	UGDA.0202308	Type III				Adaxial surface: dense indumentum distributed across the lamina, with particularly high density along the leaf margin. Cylindrical unicellular trichomes arising from multicellular basal epidermal complexes and clavate-cylindrical multicellular trichomes were present; the latter were tetracellular.				Stomata: narrowly elliptic, numerous and occurring in distinct clusters; subsidiary cells not distinctly differentiated from surrounding epidermal cells.
							Apical tooth larger than the adjacent marginal teeth.		Abaxial surface: dense indumentum distributed across the lamina, with particularly high density along the leaf margin, midrib, and lateral veins. Cylindrical unicellular trichomes arising from multicellular basal epidermal complexes and clavate-cylindrical multicellular trichomes were present; the latter were tetracellular.		Adaxial epidermis: epidermal cells irregularly polygonal; anticlinal walls distinctly sinuate.		Epicuticular wax: moderate, concentrated around the stomatal complex and subsidiary cells.

Supplementary Table S3. Nuclear DNA content of the investigated *Alchemilla* accessions

Supplementary Table S3. Nuclear DNA content of the investigated *Alchemilla* accessions							
Sample ID / plant No.	**Sample peak position**	**Sample CV (%)**	**Standard peak position**	**Standard CV (%)**	**2C DNA content (pg)**	**Mean 2C DNA content (pg)**	**Species**
Alchemilla _1_1 /51	24404	6.28	13165	6.79	3.633	3.670	*Alchemilla gracilis Opiz*
Alchemilla _1_2 /52	24625	4.57	12912	5.03	3.738		
Alchemilla _1_3 /53	23988	5.04	12979	6.18	3.623		
Alchemilla _1_4 /54	24579	4.29	13134	4.95	3.668		
Alchemilla _1_5 /55	24204	5.11	13176	4.61	3.600		
Alchemilla _1_6 /56	24947	4.75	13610	4.85	3.593		
Alchemilla _1_7 /57	24621	5.29	13078	4.79	3.690		
Alchemilla _1_8 /58	24463	4.96	12760	6.34	3.758		
Alchemilla _1_9 /59	23258	4.61	12411	4.43	3.673		
Alchemilla _1_10 /60	23883	5.83	13005	4.78	3.599		
Alchemilla _1_11 /61	25300	5.1	13053	5.16	3.799		
Alchemilla _2_1 /62	24279	6.03	13163	5.61	3.615	3.692	*Alchemilla subcrenata Buser*
Alchemilla _2_2 /63	24101	5.73	13173	5.37	3.586		
Alchemilla _2_3 /64	23786	4.77	12859	5.95	3.626		
Alchemilla _2_4 /65	24339	4.61	13179	5.31	3.620		
Alchemilla _2_5 /66	26129	4.67	13597	4.57	3.766		
Alchemilla _2_6 /67	24823	5.21	12954	5.97	3.756		
Alchemilla _2_7 /68	25017	5.66	13208	5.85	3.712		
Alchemilla _2_8 /69	25859	5.25	13395	6.47	3.784		
Alchemilla _2_9 /70	25189	5.78	13140	5.84	3.757		
Alchemilla _2_10 /71	25574	6.57	13570	5.87	3.694		
Alchemilla _2_11 /72	24386	5.35	12921	5.05	3.699		
Alchemilla _3_1 /73	23784	5.53	12940	5.92	3.603	3.559	*Alchemilla glabra Neygenf.*
Alchemilla _3_2 /74	24075	6.4	13137	5.61	3.592		
Alchemilla _3_3 /75	23395	5.15	12645	5.24	3.626		
Alchemilla _3_4 /76	24127	5.29	13210	6.09	3.580		
Alchemilla _3_5 /77	23328	4.88	12476	6.61	3.665		
Alchemilla _3_6 /78	23162	5.11	12501	5.52	3.632		
Alchemilla _3_7 /79	24163	4.99	12979	5.6	3.649		
Alchemilla _3_8 /80	25104	5.58	13261	5.86	3.710		
Alchemilla _3_9 /81	23329	6.05	13191	6	3.466		
Alchemilla _3_10 /82	23137	5.79	12966	6.14	3.497		
Alchemilla _3_11 /83	23227	5.48	12979	5.71	3.508		
Alchemilla _3_12 /84	23564	5.61	13147	6.54	3.513		
Alchemilla _3_13 /85	21587	6.3	12236	6.27	3.458		
Alchemilla _3_14 /86	23650	5.5	13150	5.3	3.525		
Alchemilla _3_15 /101	24067	5.64	13528	5.43	3.487		
Alchemilla _3_16 /102	23242	5.76	12928	5.38	3.524		
Alchemilla _3_17 /103	23500	4.89	12956	4.96	3.555		
Alchemilla _3_18 /104	23391	6.48	12880	6.07	3.560		
Alchemilla _3_19 /105	23401	6.51	12426	5.69	3.691		
Alchemilla _3_20 /106	23844	6.52	13780	6.96	3.391		
Alchemilla _3_21 /107	23626	5.95	12831	5.51	3.609		
Alchemilla _3_22 /108	22997	6	12817	5.56	3.517		
Alchemilla _3_23/109	21138	6.66	13012	6.37	3.184		
Alchemilla _3_24 /110	25142	4.88	13195	5.47	3.735		
Alchemilla _3_25 /111	24478	6.01	13142	5.63	3.651		
Alchemilla _3_26 /112	23104	4.98	12572	5.17	3.602		
Alchemilla _3_27 /113	23765	5.4	12515	6.09	3.722		
Alchemilla _4_1 /87	24053	5.51	13229	6.04	3.564	3.555	*Alchemilla glabra Neygenf.*
Alchemilla _4_2 /88	23178	5.92	12784	5.16	3.554		
Alchemilla _4_3 /89	22623	6.41	12464	6.32	3.558		
Alchemilla _4_4 /90	23146	6.2	12714	6.55	3.568		
Alchemilla _4_5 /91	23320	5.73	12700	6.31	3.599		
Alchemilla _4_6 /92	23439	6.31	12970	6.62	3.542		
Alchemilla _4_7 /93	23137	5.79	12966	6.14	3.497		
Alchemilla _4_8 /94	23122	5.21	12695	6.16	3.570		
Alchemilla _4_9 /95	23592	5	13264	5.5	3.486		
Alchemilla _4_10 /96	22510	6.32	12212	6.92	3.613		
Alchemilla _4_11 /97	23024	4.95	12687	4.96	3.557		
Alchemilla _4_12 /98	23973	6.02	13091	6.69	3.589		
Alchemilla _4_13 /99	23403	5.42	13010	6.33	3.526		
Alchemilla _4_14 /100	23392	5.81	12914	6.68	3.550		
Alchemilla _5_1 /114	24704	6.12	13073	5.64	3.704	3.717	*Alchemilla glaucescens Wallr.*
Alchemilla _5_2 /115	24379	5.74	12938	5.51	3.693		
Alchemilla _5_3 /116	24864	6	13204	4.85	3.691		
Alchemilla _5_4 /117	24820	6.06	12843	4.52	3.788		
Alchemilla _5_5 /118	23568	6.34	12255	5.23	3.769		
Alchemilla _5_6 /119	24930	6.08	13068	4.64	3.739		
Alchemilla _5_7 /120	24049	5.82	13074	4.83	3.605		
Alchemilla _5_8 /121	24571	5.89	12904	4.26	3.732		
Alchemilla _5_9 /122	25211	6.28	13255	5.24	3.728		
Alchemilla _5_10 /123	25493	6.36	13340	4.49	3.746		
Alchemilla _5_11 /124	24982	5.72	13409	4.59	3.652		
Alchemilla _5_12 /125	25378	6.86	13234	5.99	3.759		
Alchemilla _6_1 /1	24406	3.94	13073	3.85	3.659	3.628	*Alchemilla glaucescens Wallr.*
Alchemilla _6_2 /2	25419	4.65	13381	5.04	3.723		
Alchemilla _6_3 /8	23438	3.89	12963	4.02	3.544		
Alchemilla _6_4 /9	23914	4.1	13146	4.17	3.565		
Alchemilla _6_5 /10	23984	5.26	13167	4.62	3.570		
Alchemilla _6_6 /11	23857	5.97	13057	6.88	3.581		
Alchemilla _6_7 /12	25072	3.69	13107	4.57	3.749		
Alchemilla _6_8 /13	23814	4.15	13009	5.4	3.588		
Alchemilla _6_9 /14	25237	4.31	13418	4.6	3.686		
Alchemilla _6_10 /15	24195	3.95	13032	4.48	3.639		
Alchemilla _6_11 /16	23774	4.48	12949	4.91	3.599		
Alchemilla _7_1 /3	23701	4.8	13100	4.76	3.546	3.627	*Alchemilla glabra Neygenf.*
Alchemilla _7_2 /4	23442	4.72	12720	5.66	3.612		
Alchemilla _7_3 /5	24403	4.42	13186	5.31	3.627		
Alchemilla _7_4 /6	24465	4.08	13121	4.66	3.655		
Alchemilla _7_5 /7	24947	4	13232	4.3	3.695		

Alchemilla _8_1 /126	25108	6.04	13372	4.9	3.680	3.709	*Alchemilla glaucescens Wallr.*
Alchemilla _8_2 /127	24659	5.13	12888	4.42	3.750		
Alchemilla _8_3 /128	23036	6.85	12119	5.82	3.726		
Alchemilla _8_4 /129	25544	5.96	13385	4.45	3.740		
Alchemilla _8_5 /130	24689	4.21	13810	4.56	3.504		
Alchemilla _8_6 /131	24151	3.94	12812	6.1	3.695		
Alchemilla _8_7 /132	22997	6.17	13161	5.85	3.425		
Alchemilla _8_8 /133	23235	4.14	12527	5.9	3.635		
Alchemilla _8_9 /134	24835	4.01	12693	4.64	3.835		
Alchemilla _8_10 /135	24595	4.33	12951	4.21	3.722		
Alchemilla _8_11 /136	24034	5.41	12785	5.79	3.685		
Alchemilla _8_12 /137	24732	4.61	13101	4.91	3.700		
Alchemilla _8_13 /138	26253	5.13	13327	6.89	3.861		
Alchemilla _8_14 /139	24653	5.13	13273	4.72	3.640		
Alchemilla _8_15 /140	24673	4.86	12757	6.92	3.791		
Alchemilla _8_16 /141	25448	5.37	13191	6.86	3.781		
Alchemilla _8_17 /142	25746	3.86	13319	5.96	3.789		
Alchemilla _8_18 /143	25247	4.68	13312	5.31	3.717		
Alchemilla _8_19 /144	24726	5.32	12916	6.96	3.752		
Alchemilla _8_20 /145	24813	4.93	13120	6.43	3.707		
Alchemilla _8_21 /146	25976	4.38	13670	5.5	3.724		
Alchemilla _8_22 /147	23879	6.26	12614	5.03	3.710		
Alchemilla _8_23 /148	24872	5.25	13162	6.27	3.704		
Alchemilla _8_24 /149	25964	3.89	13538	5.17	3.759		
Alchemilla _8_25 /150	25841	4	13693	5.12	3.699		
Alchemilla _9_1 /17	24758	5.1	12964	5.4	3.743	3.686	*Alchemilla glaucescens Wallr.*
Alchemilla _9_2 /30	24369	5.74	12895	5.7	3.704		
Alchemilla _9_3 /31	24691	5.47	13075	4.7	3.701		
Alchemilla _9_4 /32	23410	5.66	12696	4.07	3.614		
Alchemilla _9_5 /33	24366	4.85	13025	4.15	3.667		
Alchemilla _10_1 /20	23096	6.16	12412	4.4	3.647	3.602	*Alchemilla gracilis Opiz*
Alchemilla _10_2 /21	23261	5.65	12966	4.56	3.516		
Alchemilla _10_3 /22	23354	5.45	12710	5.3	3.601		
Alchemilla _10_4 /34	23538	5.3	13106	4.94	3.520		
Alchemilla _10_5 /35	25066	4.84	13154	5.25	3.735		
Alchemilla _10_6 /36	23554	5.8	12554	4.59	3.677		
Alchemilla _10_7 /37	23364	6.9	12963	5.15	3.533		
Alchemilla _10_8 /38	23388	6.38	12727	5.43	3.602		
Alchemilla _10_9 /39	24560	5.21	13434	4.87	3.583		
Alchemilla _11_1 /23	24157	6.04	13138	4.61	3.604	3.581	*Alchemilla monticola* Opiz
Alchemilla _11_2 /24	23408	5.7	13192	4.6	3.478		
Alchemilla _11_3 /25	22338	6.26	12684	5.33	3.452		
Alchemilla _11_4 /26	23877	5.18	12896	5.27	3.629		
Alchemilla _11_5 /27	23435	4.81	12563	4.68	3.656		
Alchemilla _11_6 /28	24531	5.43	13075	5.27	3.677		
Alchemilla _11_7 /29	23847	5.44	13099	5.16	3.568		
Alchemilla _12_1 /40	25024	4.87	13963	4.17	3.513	3.556	*Alchemilla subglobosa* C.G.Westerl.
Alchemilla _12_2 /41	24445	5.41	13289	4.84	3.605		
Alchemilla _12_3 /42	24214	5.93	13419	4.32	3.537		
Alchemilla _12_4 /43	24133	6.15	13115	6.21	3.607		
Alchemilla _12_5 /44	22318	6.93	12428	4.88	3.520		
Alchemilla _12_6 /45	23235	5.87	12806	3.75	3.556		
Alchemilla _13_1 /46	24478	5.59	13213	5.33	3.631	3.634	*Alchemilla glaucescens* Wallr.
Alchemilla _13_2 /47	24044	4.79	12858	4.15	3.665		
Alchemilla _13_3 /48	24233	4.71	13169	4.25	3.607		
Alchemilla _14_1 /50	23662	5.32	13068	4.34	3.549	3.688	*Alchemilla mollis (Buser) Rothm.*
Alchemilla _14_2 /151	25301	4.43	13170	5.19	3.765		
Alchemilla _14_3 /152	23196	5.31	13006	6.16	3.496		
Alchemilla _14_4 /153	23319	4.79	13129	6.65	3.481		
Alchemilla _14_5 /154	28872	4.73	13010	5.65	4.350		
Alchemilla _14_6 /155	24203	4.43	13599	5.46	3.488		
Alchemilla _15_1 /156	24159	5.51	13345	4.52	3.548	3.581	*Alchemilla mollis (Buser) Rothm.*
Alchemilla _15_2 /157	24873	5.07	13592	4.73	3.587		
Alchemilla _15_3 /158	23922	5.24	12937	5.88	3.624		
Alchemilla _15_4 /159	23489	5.75	12920	6.83	3.563		
Alchemilla _16_1 /160	24438	6.27	13464	5.17	3.558	3.521	*Alchemilla hirsuticaulis H.Lindb.*
Alchemilla _16_2 /161	23834	5.48	12942	5.48	3.610		
Alchemilla _16_3 /162	23453	4.65	13223	5.13	3.476		
Alchemilla _16_4 /163	23037	4.86	12643	6.52	3.571		
Alchemilla _16_5 /164	23258	5.23	13138	5.28	3.470		
Alchemilla _16_6 /165	23837	5.58	13575	5.56	3.442		

Note: Samples were prepared using nuclei isolation buffer supplemented with 1% PVP, PI and RNAse. *Solanum lycopersicum* 'Stupicke' (1.96 pg/2C) was used as an internal standard. Measurements were performed using a Sysmex CyFlow flow cytometer.

Supplementary Table S4. Identification of sequence labels used in the *matK*, *rpoC1* and *trnH-psbA* analyses.

Supplementary Table S4. Identification of sequence labels used in the *matK*, *rpoC1* and *trnH-psbA* analyses.			
matK **(n = 95; This study = 46; GenBank = 49)**			
Sequence label	**Species**	**Source**	**GenBank accession No.**
Alchemilla_gracilis_1	*Alchemilla gracilis* Opiz	This study	PZ784175
Alchemilla_gracilis_2	*Alchemilla gracilis* Opiz	This study	PZ792307
Alchemilla_gracilis_3	*Alchemilla gracilis* Opiz	This study	PZ784176
Alchemilla_gracilis_4	*Alchemilla gracilis* Opiz	This study	PZ784194
Alchemilla_subcrenata_5	*Alchemilla subcrenata* Buser	This study	PZ784177
Alchemilla_subcrenata_6	*Alchemilla subcrenata* Buser	This study	PZ784178
Alchemilla_subcrenata_7	*Alchemilla subcrenata* Buser	This study	PZ784179
Alchemilla_subcrenata_8	*Alchemilla subcrenata* Buser	This study	PZ784180
Alchemilla_subcrenata_9	*Alchemilla subcrenata* Buser	This study	PZ784196
Alchemilla_glabra_10	*Alchemilla glabra* Neygenf.	This study	PZ784182
Alchemilla_glabra_11	*Alchemilla glabra* Neygenf.	This study	PZ784185
Alchemilla_glabra_12	*Alchemilla glabra* Neygenf.	This study	PZ784190
Alchemilla_glabra_13	*Alchemilla glabra* Neygenf.	This study	PZ784191
Alchemilla_glabra_14	*Alchemilla glabra* Neygenf.	This study	PZ784213
Alchemilla_glabra_15	*Alchemilla glabra* Neygenf.	This study	PZ784192
Alchemilla_glabra_16	*Alchemilla glabra* Neygenf.	This study	PZ784186
Alchemilla_glabra_17	*Alchemilla glabra* Neygenf.	This study	PZ784211
Alchemilla_glabra_18	*Alchemilla glabra* Neygenf.	This study	PZ784198
Alchemilla_glabra_19	*Alchemilla glabra* Neygenf.	This study	PZ784184
Alchemilla_glabra_20	*Alchemilla glabra* Neygenf.	This study	PZ784193
Alchemilla_glabra_21	*Alchemilla glabra* Neygenf.	This study	PZ784181
Alchemilla_glabra_22	*Alchemilla glabra* Neygenf.	This study	PZ784187
Alchemilla_glabra_23	*Alchemilla glabra* Neygenf.	This study	PZ784174
Alchemilla_glaucescens_24	*Alchemilla glaucescens* Wallr.	This study	PZ784199
Alchemilla_glaucescens_25	*Alchemilla glaucescens* Wallr.	This study	PZ784205
Alchemilla_glaucescens_26	*Alchemilla glaucescens* Wallr.	This study	PZ784214
Alchemilla_glabra_27	*Alchemilla glabra* Neygenf.	This study	PZ784202
Alchemilla_glabra_28	*Alchemilla glabra* Neygenf.	This study	PZ792308
Alchemilla_glabra_29	*Alchemilla glabra* Neygenf.	This study	PZ784215
Alchemilla_glaucescens_30	*Alchemilla glaucescens* Wallr.	This study	PZ784208
Alchemilla_glaucescens_31	*Alchemilla glaucescens* Wallr.	This study	PZ784207
Alchemilla_glaucescens_32	*Alchemilla glaucescens* Wallr.	This study	PZ784206
Alchemilla_glaucescens_33	*Alchemilla glaucescens* Wallr.	This study	PZ784203
Alchemilla_glaucescens_34	*Alchemilla glaucescens* Wallr.	This study	PZ784197
Alchemilla_glaucescens_36	*Alchemilla glaucescens* Wallr.	This study	PZ784195
Alchemilla_glaucescens_37	*Alchemilla glaucescens* Wallr.	This study	PZ784204
Alchemilla_gracilis_38	*Alchemilla gracilis* Opiz	This study	PZ784209
Alchemilla_gracilis_39	*Alchemilla gracilis* Opiz	This study	PZ784210
Alchemilla_monticola_40	*Alchemilla monticola* Opiz	This study	PZ784201
Alchemilla_glaucescens_41	*Alchemilla glaucescens* Wallr.	This study	PZ784173
Alchemilla_glaucescens_42	*Alchemilla glaucescens* Wallr.	This study	PZ784200
Alchemilla_monticola_44	*Alchemilla monticola* Opiz	This study	PZ784212
Alchemilla_glaucescens_46	*Alchemilla glaucescens* Wallr.	This study	PZ784183
Alchemilla_mollis_47	*Alchemilla mollis* (Buser) Rothm.	This study	PZ784216
Alchemilla_mollis_48	*Alchemilla mollis* (Buser) Rothm.	This study	PZ784188
Alchemilla_hirsuticaulis_49	*Alchemilla hirsuticaulis* H.Lindb.	This study	PZ784189
Alchemilla_acutiloba_KF997313	*Alchemilla acutiloba* Opiz	GenBank	KF997313
Alchemilla_acutiloba_MK925913	*Alchemilla acutiloba* Opiz	GenBank	MK925913
Alchemilla_acutiloba_MK926244	*Alchemilla acutiloba* Opiz	GenBank	MK926244
Alchemilla_alpina_KF997340	*Alchemilla alpina* L.	GenBank	KF997340
Alchemilla_alpina_MK925964	*Alchemilla alpina* L.	GenBank	MK925964
Alchemilla_alpina_MK926124	*Alchemilla alpina* L.	GenBank	MK926124
Alchemilla_alpina_MK926135	*Alchemilla alpina* L.	GenBank	MK926135
Alchemilla_alpina_MK926296	*Alchemilla alpina* L.	GenBank	MK926296
Alchemilla_arguteserrata_PV256519	*Alchemilla arguteserrata* H.Lindb. ex	GenBank	PV256519
Alchemilla_argyrophylla_ON982103	*Alchemilla argyrophylla* Oliv.	GenBank	ON982103
Alchemilla_changaica_PV256516	*Alchemilla changaica* V.N.Tikhom.	GenBank	PV256516
Alchemilla_circularis_PV256521	*Alchemilla circularis* Juz.	GenBank	PV256521
Alchemilla_cyrtopleura_PV256520	*Alchemilla cyrtopleura* Juz.	GenBank	PV256520
Alchemilla_filicaulis_JN894290	*Alchemilla filicaulis* Buser	GenBank	JN894290
Alchemilla_filicaulis_JN894583	*Alchemilla filicaulis* Buser	GenBank	JN894583
Alchemilla_filicaulis_KF997456	*Alchemilla filicaulis* Buser	GenBank	KF997456
Alchemilla_filicaulis_MK925590	*Alchemilla filicaulis* Buser	GenBank	MK925590
Alchemilla_glabra_JN894466	*Alchemilla glabra* Neygenf.	GenBank	JN894466
Alchemilla_glabra_JN894582	*Alchemilla glabra* Neygenf.	GenBank	JN894582

Alchemilla_glabra_JN895008	*Alchemilla glabra* Neygenf.	GenBank	JN895008
Alchemilla_glabra_MK925651	*Alchemilla glabra* Neygenf.	GenBank	MK925651
Alchemilla_glabra_MK925849	*Alchemilla glabra* Neygenf.	GenBank	MK925849
Alchemilla_glabra_MK926211	*Alchemilla glabra* Neygenf.	GenBank	MK926211
Alchemilla_glaucescens_KF997355	*Alchemilla glaucescens* Wallr.	GenBank	KF997355
Alchemilla_glaucescens_MK925968	*Alchemilla glaucescens* Wallr.	GenBank	MK925968
Alchemilla_glaucescens_MK926314	*Alchemilla glaucescens* Wallr.	GenBank	MK926314
Alchemilla_glomerulans_KF997376	*Alchemilla glomerulans* Buser	GenBank	KF997376
Alchemilla_glomerulans_MK925682	*Alchemilla glomerulans* Buser	GenBank	MK925682
Alchemilla_gubanovii_PV256517	*Alchemilla gubanovii* V.N.Tikhom.	GenBank	PV256517
Alchemilla_hebescens_PV256522	*Alchemilla hebescens* Juz.	GenBank	PV256522
Alchemilla_japonica_AB073681	*Alchemilla japonica* Nakai & H.Hara	GenBank	AB073681
Alchemilla_japonica_LC759999	*Alchemilla japonica* Nakai & H.Hara	GenBank	LC759999
Alchemilla_japonica_MN434022	*Alchemilla japonica* Nakai & H.Hara	GenBank	MN434022
Alchemilla_japonica_MN434023	*Alchemilla japonica* Nakai & H.Hara	GenBank	MN434023
Alchemilla_johnstonii_ON982104	*Alchemilla johnstonii* Oliv.	GenBank	ON982104
Alchemilla_micans_KF997394	*Alchemilla micans* Buser	GenBank	KF997394
Alchemilla_mollis_KF997320	*Alchemilla mollis* (Buser) Rothm.	GenBank	KF997320
Alchemilla_mollis_KF997444	*Alchemilla mollis* (Buser) Rothm.	GenBank	KF997444
Alchemilla_pavlovii_PV256518	*Alchemilla pavlovii* Juz.	GenBank	PV256518
Alchemilla_pectinata_OQ290277	*Alchemilla pectinata* Kunth	GenBank	OQ290277
Alchemilla_tianschanica_MF158691	*Alchemilla tianschanica* Juz.	GenBank	MF158691
Alchemilla_tianschanica_MK954200	*Alchemilla tianschanica* Juz.	GenBank	MK954200
Alchemilla_wichurae_KF997398	*Alchemilla wichurae* (Buser) Stefánsson	GenBank	KF997398
Alchemilla_wichurae_MK925598	*Alchemilla wichurae* (Buser) Stefánsson	GenBank	MK925598
Alchemilla_xanthochlora_JN894036	*Alchemilla xanthochlora* Rothm.	GenBank	JN894036
Alchemilla_xanthochlora_JN895007	*Alchemilla xanthochlora* Rothm.	GenBank	JN895007
Alchemilla_xanthochlora_JN895898	*Alchemilla xanthochlora* Rothm.	GenBank	JN895898
Alchemilla_xanthochlora_MK925898	*Alchemilla xanthochlora* Rothm.	GenBank	MK925898
Comarum_palustre_JN966247	*Comarum palustre* L.	GenBank	JN966247
***rpoC1* (n = 64; This study = 48; GenBank = 16)**			
Sequence label	**Species**	**Source**	**GenBank accession No.**
Alchemilla_1spr	*Alchemilla gracilis* Opiz	This study	PZ784260
Alchemilla_3R	*Alchemilla gracilis* Opiz	This study	PZ784257
Alchemilla_4spr	*Alchemilla gracilis* Opiz	This study	PZ784263
Alchemilla_5	*Alchemilla subcrenata* Buser	This study	PZ784217
Alchemilla_6	*Alchemilla subcrenata* Buser	This study	PZ784252
Alchemilla_7	*Alchemilla subcrenata* Buser	This study	PZ784259
Alchemilla_8	*Alchemilla subcrenata* Buser	This study	PZ784235
Alchemilla_9R	*Alchemilla subcrenata* Buser	This study	PZ784261
Alchemilla_10	*Alchemilla glabra* Neygenf.	This study	PZ784218
Alchemilla_11	*Alchemilla glabra* Neygenf.	This study	PZ784224
Alchemilla_12	*Alchemilla glabra* Neygenf.	This study	PZ784222
Alchemilla_13	*Alchemilla glabra* Neygenf.	This study	PZ784226
Alchemilla_14	*Alchemilla glabra* Neygenf.	This study	PZ784225
Alchemilla_15	*Alchemilla glabra* Neygenf.	This study	PZ784223
Alchemilla_16	*Alchemilla glabra* Neygenf.	This study	PZ784219
Alchemilla_17	*Alchemilla glabra* Neygenf.	This study	PZ784240
Alchemilla_18	*Alchemilla glabra* Neygenf.	This study	PZ784229
Alchemilla_19	*Alchemilla glabra* Neygenf.	This study	PZ784220
Alchemilla_20	*Alchemilla glabra* Neygenf.	This study	PZ784228
Alchemilla_21	*Alchemilla glabra* Neygenf.	This study	PZ784234
Alchemilla_22	*Alchemilla glabra* Neygenf.	This study	PZ784236
Alchemilla_23	*Alchemilla glabra* Neygenf.	This study	PZ784241
Alchemilla_24	*Alchemilla glaucescens* Wallr.	This study	PZ784232
Alchemilla_25	*Alchemilla glaucescens* Wallr.	This study	PZ784233
Alchemilla_26	Alchemilla glaucescens Wallr.	This study	PZ784238
Alchemilla_27	*Alchemilla glabra* Neygenf.	This study	PZ784246
Alchemilla_28	*Alchemilla glabra* Neygenf.	This study	PZ784243
Alchemilla_29	*Alchemilla glabra* Neygenf.	This study	PZ784247
Alchemilla_30	*Alchemilla glaucescens* Wallr.	This study	PZ784245
Alchemilla_31	*Alchemilla glaucescens* Wallr.	This study	PZ784237
Alchemilla_32	*Alchemilla glaucescens* Wallr.	This study	PZ784221
Alchemilla_33	*Alchemilla glaucescens* Wallr.	This study	PZ784250
Alchemilla_34	*Alchemilla glaucescens* Wallr.	This study	PZ784239
Alchemilla_35	*Alchemilla glaucescens* Wallr.	This study	PZ784264
Alchemilla_36	*Alchemilla glaucescens* Wallr.	This study	PZ784244
Alchemilla_37	*Alchemilla glaucescens* Wallr.	This study	PZ784242
Alchemilla_38	*Alchemilla gracilis* Opiz	This study	PZ784258
Alchemilla_39	*Alchemilla gracilis* Opiz	This study	PZ784253
Alchemilla_40	*Alchemilla monticola* Opiz	This study	PZ784227
Alchemilla_41	*Alchemilla glaucescens* Wallr.	This study	PZ784254

Alchemilla_42	*Alchemilla glaucescens* Wallr.	This study	PZ784230
Alchemilla_43	*Alchemilla gracilis* Opiz	This study	PZ784255
Alchemilla_44	*Alchemilla monticola* Opiz	This study	PZ784262
Alchemilla_45	*Alchemilla subglobosa* G.C.Westerl.	This study	PZ784251
Alchemilla_46	*Alchemilla glaucescens* Wallr.	This study	PZ784231
Alchemilla_47	*Alchemilla mollis* (Buser) Rothm.	This study	PZ784256
ALchemilla_48	*Alchemilla mollis* (Buser) Rothm.	This study	PZ784248
Alchemilla_49	*Alchemilla hirsuticaulis* H.Lindb.	This study	PZ784249
C_Alchemilla_acutiloba_KY420009	*Alchemilla acutiloba* Opiz	GenBank	KY420009
C_Alchemilla_argyrophylla_NC_049037	*Alchemilla argyrophylla* Oliv.	GenBank	NC_049037
C_Alchemilla_exigua_PP316508	*Alchemilla exigua* Buser	GenBank	PP316508
C_Alchemilla_faeroensis_OZ360792	*Alchemilla faeroensis* (Lange) Buser	GenBank	OZ360792
C_Alchemilla_glaucescens_PP316509	*Alchemilla glaucescens* Wallr.	GenBank	PP316509
C_Alchemilla_guatemalensis_NC_087026	*Alchemilla guatemalensis* Rothm.	GenBank	NC_087026
C_Alchemilla_holosericea_NC_087027	*Alchemilla holosericea* L.M.Perry	GenBank	NC_087027
C_Alchemilla_microcarpa_NC_087047	*Alchemilla microcarpa* Boiss. & Reut.	GenBank	NC_087047
C_Alchemilla_monticola_PP316510	*Alchemilla monticola* Opiz	GenBank	PP316510
C_Alchemilla_orbiculata_NC_087025	*Alchemilla orbiculata* Ruiz & Pav.	GenBank	NC_087025
C_Alchemilla_pectinata_KY419937	*Alchemilla pectinata* Kunth	GenBank	KY419937
C_Alchemilla_pedata_NC_049038	*Alchemilla pedata* Hochst. ex A.Rich.	GenBank	NC_049038
C_Alchemilla_transiens_PP316511	*Alchemilla transiens* (Buser) Buser	GenBank	PP316511
C_Alchemilla_vetteri_PX223350	*Alchemilla vetteri* Buser	GenBank	PX223350
C_Alchemilla_vulcanica_NC_087024	*Alchemilla vulcanica* Cham. & Schltdl.	GenBank	NC_087024
Comarum_palustre_Li_QQ_20170816001	*Comarum palustre* L.	GenBank	Li QQ 20170816001

trnH-psbA **(n = 61; This study = 43; GenBank = 18)**

Sequence label	Species	Source	GenBank accession No.
Alchemilla_gracilis_1	*Alchemilla gracilis* Opiz	This study	PZ784265
Alchemilla_gracilis_2	Alchemilla gracilis Opiz	This study	PZ784269
ALchemilla_gracilis_3	*Alchemilla gracilis* Opiz	This study	PZ784267
Alchemilla_gracilis_4	*Alchemilla gracilis* Opiz	This study	PZ784273
ALchemilla_subcrenata_5	*Alchemilla subcrenata* Buser	This study	PZ784268
Alchemilla_subcrenata_6	*Alchemilla subcrenata* Buser	This study	PZ784266
ALchemilla_subcrenata_7	*Alchemilla subcrenata* Buser	This study	PZ784278
Alchemilla_subcrenata_8	*Alchemilla subcrenata* Buser	This study	PZ784282
ALchemilla_subcrenata_9	*Alchemilla subcrenata* Buser	This study	PZ784293
Alchemilla_glabra_10	*Alchemilla glabra* Neygenf.	This study	PZ784280
Alchemilla_glabra_11	*Alchemilla glabra* Neygenf.	This study	PZ784299
Alchemilla_glabra_12	*Alchemilla glabra* Neygenf.	This study	PZ784300
Alchemilla_glabra_13	*Alchemilla glabra* Neygenf.	This study	PZ784303
Alchemilla_glabra_14	*Alchemilla glabra* Neygenf.	This study	PZ784301
Alchemilla_glabra_15	*Alchemilla glabra* Neygenf.	This study	PZ784302
ALchemilla_glabra_16	*Alchemilla glabra* Neygenf.	This study	PZ784290
ALchemilla_glabra_17	*Alchemilla glabra* Neygenf.	This study	PZ784291
ALchemilla_glabra_19	*Alchemilla glabra* Neygenf.	This study	PZ784304
Alchemilla_glabra_20	*Alchemilla glabra* Neygenf.	This study	PZ784274
Alchemilla_glabra_21	*Alchemilla glabra* Neygenf.	This study	PZ784288
Alchemilla_glabra_22	*Alchemilla glabra* Neygenf.	This study	PZ784275
Alchemilla_glabra_23	*Alchemilla glabra* Neygenf.	This study	PZ784279
Alchemilla_glaucescens_24	*Alchemilla glaucescens* Wallr.	This study	PZ784277
Alchemilla_glaucescens_25	*Alchemilla glaucescens* Wallr.	This study	PZ784296
Alchemilla_glaucescens_26	*Alchemilla glaucescens* Wallr.	This study	PZ784284
Alchemilla_glabra_27spr	*Alchemilla glabra* Neygenf.	This study	PZ784295
Alchemilla_glabra_28spr	*Alchemilla glabra* Neygenf.	This study	PZ784307
Alchemilla_glaucescens_31	*Alchemilla glaucescens* Wallr.	This study	PZ784294
Alchemilla_glaucescens_32	*Alchemilla glaucescens* Wallr.	This study	PZ784286
Alchemilla_glaucescens_33	*Alchemilla glaucescens* Wallr.	This study	PZ784287
Alchemilla_glaucescens_34	*Alchemilla glaucescens* Wallr.	This study	PZ784292
Alchemilla_glaucescens_35spr	*Alchemilla glaucescens* Wallr.	This study	PZ784297
Alchemilla_glaucescens_37	*Alchemilla glaucescens* Wallr.	This study	PZ784289
Alchemilla_gracilis_39spr	*Alchemilla gracilis* Opiz	This study	PZ784271
Alchemilla_glaucescens_41	*Alchemilla glaucescens* Wallr.	This study	PZ784272
Alchemilla_glaucescens_42spr	*Alchemilla glaucescens* Wallr.	This study	PZ784306
ALchemilla_gracilis_43	*Alchemilla gracilis* Opiz	This study	PZ784270
Alchemilla_monticola_44	*Alchemilla monticola* Opiz	This study	PZ784285
Alchemilla_subglobosa_45	*Alchemilla subglobosa* G.C.Westerl.	This study	PZ784276
Alchemilla_glaucescens_46	*Alchemilla glaucescens* Wallr.	This study	PZ784305
Alchemilla_mollis_47	*Alchemilla mollis* (Buser) Rothm.	This study	PZ784281
Alchemilla_mollis_48	*Alchemilla mollis* (Buser) Rothm.	This study	PZ784298
Alchemilla_hirsuticaulis_49	*Alchemilla hirsuticaulis* H.Lindb.	This study	PZ784283
Alchemilla_acutiloba_KY420009	*Alchemilla acutiloba* Opiz	GenBank	KY420009
Alchemilla_argyrophylla_NC_049037	*Alchemilla argyrophylla* Oliv.	GenBank	NC_049037
Alchemilla_exigua_PP316508	*Alchemilla exigua* Buser	GenBank	PP316508

Alchemilla_faeroensis_OZ360792	*Alchemilla faeroensis* (Lange) Buser	GenBank	OZ360792
Alchemilla_glaucescens_PP316509	*Alchemilla glaucescens* Wallr.	GenBank	PP316509
Alchemilla_guatemalensis_NC_087026	*Alchemilla guatemalensis* Rothm.	GenBank	NC_087026
Alchemilla_holosericea_NC_087027	*Alchemilla holosericea* L.M.Perry	GenBank	NC_087027
Alchemilla_microcarpa_NC_087047	*Alchemilla microcarpa* Boiss. & Reut.	GenBank	NC_087047
Alchemilla_monticola_PP316510	*Alchemilla monticola* Opiz	GenBank	PP316510
Alchemilla_nemoralis_OM638614	*Alchemilla nemoralis* Alechin	GenBank	OM638614
Alchemilla_orbiculata_NC_087025	*Alchemilla orbiculata* Ruiz & Pav.	GenBank	NC_087025
Alchemilla_pectinata_KY419937	*Alchemilla pectinata* Kunth	GenBank	KY419937
Alchemilla_pedata_NC_049038	*Alchemilla pedata* Hochst. ex A.Rich.	GenBank	NC_049038
Alchemilla_transiens_PP316511	*Alchemilla transiens* (Buser) Buser	GenBank	PP316511
Alchemilla_vetteri_PX223350	*Alchemilla vetteri* Buser	GenBank	PX223350
Alchemilla_vulcanica_NC_087024	*Alchemilla vulcanica* Cham. & Schltdl.	GenBank	NC_087024
Alchemilla_vulgaris_PQ348714	*Alchemilla vulgaris* L.	GenBank	PQ348714
Comarum_palustre_OX637594	*Comarum palustre* L.	GenBank	OX637594

Supplementary Table S5. Molecular herbarium specimen of *Alchemilla* L. (Rosaceae).

Supplementary Table S5. Molecular herbarium specimen of *Alchemilla* L. (Rosaceae).					
AKC No.	**GenBank No.**	**Species**	**Voucher**	**Location**	**Coordinates**
1	ITS: PZ745178 matK: PZ784175 rpoC1: PZ784260 trnH-psbA: PZ784265	*Alchemilla gracilis Opiz*	UGDA.0058554	Wirty, near Arboretum Wirty, Pomeranian Voivodeship, Poland	53.9011, 18.378
2	ITS: PZ745183 matK: PZ792307 trnH-psbA: PZ784269	*Alchemilla gracilis Opiz*	UGDA.0058554	Wirty, near Arboretum Wirty, Pomeranian Voivodeship, Poland	53.9011, 18.378
3	ITS: PZ745187 matK: PZ784176 rpoC1: PZ784257 trnH-psbA: PZ784267	*Alchemilla gracilis Opiz*	UGDA.0058554	Wirty, near Arboretum Wirty, Pomeranian Voivodeship, Poland	53.9011, 18.378
4	ITS: PZ745198 matK: PZ784194 rpoC1: PZ784263 trnH-psbA: PZ784273	*Alchemilla gracilis Opiz*	UGDA.0058554	Wirty, near Arboretum Wirty, Pomeranian Voivodeship, Poland	53.9011, 18.378
5	ITS: PZ745193 matK: PZ784177 rpoC1: PZ784217 trnH-psbA: PZ784268	*Alchemilla subcrenata* Buser	UGDA.0109003	Mrzezino, south of the village, north of the Reda River, Puck County, Pomeranian Voivodeship, Poland	54.64437, 18.43296
6	ITS: PZ745184 matK: PZ784178 rpoC1: PZ784252 trnH-psbA: PZ784266	*Alchemilla subcrenata* Buser	UGDA.0109003	Mrzezino, south of the village, north of the Reda River, Puck County, Pomeranian Voivodeship, Poland	54.64437, 18.43296
7	ITS: PZ745207 matK: PZ784179 rpoC1: PZ784259 trnH-psbA: PZ784278	*Alchemilla subcrenata* Buser	UGDA.0109003	Mrzezino, south of the village, north of the Reda River, Puck County, Pomeranian Voivodeship, Poland	54.64437, 18.43296
8	ITS: PZ745191 matK: PZ784180 rpoC1: PZ784235 trnH-psbA: PZ784282	*Alchemilla subcrenata* Buser	UGDA.0109003	Mrzezino, south of the village, north of the Reda River, Puck County, Pomeranian Voivodeship, Poland	54.64437, 18.43296
9	ITS: PZ745182 matK: PZ784196 rpoC1: PZ784261 trnH-psbA: PZ784293	*Alchemilla subcrenata* Buser	UGDA.0109003	Mrzezino, south of the village, north of the Reda River, Puck County, Pomeranian Voivodeship, Poland	54.64437, 18.43296
10	ITS: PZ745217 matK: PZ784182 rpoC1: PZ784218 trnH-psbA: PZ784280	*Alchemilla glabra* Neygenf.	UGDA.0109002	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland	54.62009, 18.21020
11	ITS: PZ745215 matK: PZ784185 rpoC1: PZ784224 trnH-psbA: PZ784299	*Alchemilla glabra* Neygenf.	UGDA.0109002	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland	54.62009, 18.21020
12	ITS: PZ745209 matK: PZ784190 rpoC1: PZ784222 trnH-psbA: PZ784300	*Alchemilla glabra* Neygenf.	UGDA.0109002	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland	54.62009, 18.21020
13	ITS: PZ745216 matK: PZ784191 rpoC1: PZ784226 trnH-psbA: PZ784303	*Alchemilla glabra* Neygenf.	UGDA.0109002	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland	54.62009, 18.21020
14	ITS: PZ745214 matK: PZ784213 rpoC1: PZ784225 trnH-psbA: PZ784301	*Alchemilla glabra* Neygenf.	UGDA.0109002	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland	54.62009, 18.21020
15	ITS: PZ745208 matK: PZ784192 rpoC1: PZ784223 trnH-psbA: PZ784302	*Alchemilla glabra* Neygenf.	UGDA.0109002	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland	54.62009, 18.21020
16	ITS: PZ745212 matK: PZ784186 rpoC1: PZ784219 trnH-psbA: PZ784290	*Alchemilla glabra* Neygenf.	UGDA.0109002	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland	54.62009, 18.21020
17	ITS: PZ745211 matK: PZ784211 rpoC1: PZ784240 trnH-psbA: PZ784291	*Alchemilla glabra* Neygenf.	UGDA.0109002	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland	54.62009, 18.21020
18	matK: PZ784198 rpoC1: PZ784229	*Alchemilla glabra* Neygenf.	UGDA.0109006	Przetoczyno area, Szemud Commune, Wejherowo County, Pomeranian Voivodeship, Poland	54.42769, 18.49034
19	ITS: PZ745197 matK: PZ784184 rpoC1: PZ784220 trnH-psbA: PZ784304	*Alchemilla glabra* Neygenf.	UGDA.0109006	Przetoczyno area, Szemud Commune, Wejherowo County, Pomeranian Voivodeship, Poland	54.42769, 18.49034
20	ITS: PZ745213 matK: PZ784193 rpoC1: PZ784228 trnH-psbA: PZ784274	*Alchemilla glabra* Neygenf.	UGDA.0109006	Przetoczyno area, Szemud Commune, Wejherowo County, Pomeranian Voivodeship, Poland	54.42769, 18.49034
21	ITS: PZ745206 matK: PZ784181 rpoC1: PZ784234 trnH-psbA: PZ784288	*Alchemilla glabra* Neygenf.	UGDA.0109006	Przetoczyno area, Szemud Commune, Wejherowo County, Pomeranian Voivodeship, Poland	54.42769, 18.49034
22	ITS: PZ745210 matK: PZ784187 rpoC1: PZ784236 trnH-psbA: PZ784275	*Alchemilla glabra* Neygenf.	UGDA.0109006	Przetoczyno area, Szemud Commune, Wejherowo County, Pomeranian Voivodeship, Poland	54.42769, 18.49034

23	matK: PZ784174 rpoC1: PZ784241 trnH-psbA: PZ784279	*Alchemilla glabra* Neygenf.	UGDA.0109006	Przetoczyno area, Szemud Commune, Wejherowo County, Pomeranian Voivodeship, Poland	54.42769, 18.49034
24	ITS: PZ745190 matK: PZ784199 rpoC1: PZ784232 trnH-psbA: PZ784277	*Alchemilla glaucescens* Wallr.	UGDA.0057412	Rąb, Otalżyńska Street, Przodkowo Commune, Kartuzy County, Pomeranian Voivodeship, Poland	54.42380, 18.22653
25	ITS: PZ745188 matK: PZ784205 rpoC1: PZ784233 trnH-psbA: PZ784296	*Alchemilla glaucescens* Wallr.	UGDA.0057412	Rąb, Otalżyńska Street, Przodkowo Commune, Kartuzy County, Pomeranian Voivodeship, Poland	54.42380, 18.22653
26	ITS: PZ745179 matK: PZ784214 rpoC1: PZ784238 trnH-psbA: PZ784284	*Alchemilla glaucescens* Wallr.	UGDA.0057412	Rąb, Otalżyńska Street, Przodkowo Commune, Kartuzy County, Pomeranian Voivodeship, Poland	54.42380, 18.22653
27	ITS: PZ745189 matK: PZ784202 rpoC1: PZ784246 trnH-psbA: PZ784295	*Alchemilla glabra* Neygenf.	UGDA.0109002	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland	54.62849, 18.21634
28	rpoC1: PZ784243 matK: PZ792308 trnH-psbA: PZ784307	*Alchemilla glabra* Neygenf.	UGDA.0109002	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland	54.62849, 18.21634
29	matK: PZ784215 rpoC1: PZ784247	*Alchemilla glabra* Neygenf.	UGDA.0202306	Ustarbowo, Wejherowo Commune, Wejherowo County, Pomeranian Voivodeship, Poland	54.55825, 18.20728
30	matK: PZ784208 rpoC1: PZ784245	*Alchemilla glaucescens* Wallr.	UGDA.0109015	Kochanowo area, near the Góra Forest District headquarters, Luzino Commune, Wejherowo County, Pomeranian Voivodeship, Poland	54.615308, 18.110520
31	matK: PZ784207 rpoC1: PZ784237 trnH-psbA: PZ784294	*Alchemilla glaucescens* Wallr.	UGDA.0109015	Kochanowo area, near the Góra Forest District headquarters, Luzino Commune, Wejherowo County, Pomeranian Voivodeship, Poland	54.615308, 18.110520
32	matK: PZ784206 rpoC1: PZ784221 trnH-psbA: PZ784286	*Alchemilla glaucescens* Wallr.	UGDA.0109015	Kochanowo area, near the Góra Forest District headquarters, Luzino Commune, Wejherowo County, Pomeranian Voivodeship, Poland	54.615308, 18.110520
33	ITS: PZ745181 matK: PZ784203 rpoC1: PZ784250 trnH-psbA: PZ784287	*Alchemilla glaucescens* Wallr.	UGDA.0202305	Osowa district, city of Gdańsk, Pomeranian Voivodeship, Poland	54.4180515, 18.4423830
34	ITS: PZ745201 matK: PZ784197 rpoC1: PZ784239 trnH-psbA: PZ784292	*Alchemilla glaucescens* Wallr.	UGDA.0202305	Osowa district, city of Gdańsk, Pomeranian Voivodeship, Poland	54.4180515, 18.4423830
35	ITS: PZ745194 rpoC1: PZ784264 trnH-psbA: PZ784297	*Alchemilla glaucescens* Wallr.	UGDA.0202305	Osowa district, city of Gdańsk, Pomeranian Voivodeship, Poland	54.4180515, 18.4423830
36	ITS: PZ745205 matK: PZ784195 rpoC1: PZ784244	*Alchemilla glaucescens* Wallr.	UGDA.0202305	Osowa district, city of Gdańsk, Pomeranian Voivodeship, Poland	54.4180515, 18.4423830
37	ITS: PZ745199 matK: PZ784204 rpoC1: PZ784242 trnH-psbA: PZ784289	*Alchemilla glaucescens* Wallr.	UGDA.0202305	Osowa district, city of Gdańsk, Pomeranian Voivodeship, Poland	54.4180515, 18.4423830
38	ITS: PZ745200 matK: PZ784209 rpoC1: PZ784258	*Alchemilla gracilis Opiz*	UGDA.0173624	Witów, Tatra County, Lesser Poland Voivodeship, Poland	49.3224, 19.8209
39	ITS: PZ745196 matK: PZ784210 rpoC1: PZ784253 trnH-psbA: PZ784271	*Alchemilla gracilis Opiz*	UGDA.0173624	Witów, Tatra County, Lesser Poland Voivodeship, Poland	49.3224, 19.8209
40	matK: PZ784201 rpoC1: PZ784227	*Alchemilla monticola* Opiz	UGDA.0202307	Murzasichle vicinity (near Zakopane), Tatra County, Lesser Poland Voivodeship, Poland	49.3117, 20.0436
41	ITS: PZ745195 matK: PZ784173 rpoC1: PZ784254 trnH-psbA: PZ784272	*Alchemilla glaucescens* Wallr.	UGDA. 0173599	Gile (near Stasiki), Zakopane vicinity, Tatra County, Lesser Poland Voivodeship, Poland	49.3695, 20.0667
42	ITS: PZ745185 matK: PZ784200 rpoC1: PZ784230 trnH-psbA: PZ784306	*Alchemilla glaucescens* Wallr.	UGDA. 0173599	Gile (near Stasiki), Zakopane vicinity, Tatra County, Lesser Poland Voivodeship, Poland	49.3695, 20.0667
43	ITS: PZ745192 rpoC1: PZ784255 trnH-psbA: PZ784270	*Alchemilla gracilis* Opiz	UGDA.0173624	Witów, Tatra County, Lesser Poland Voivodeship, Poland	49.3224, 19.8209
44	matK: PZ784212 rpoC1: PZ784262 trnH-psbA: PZ784285	*Alchemilla monticola* Opiz	UGDA.0202307	Murzasichle vicinity (near Zakopane), Tatra County, Lesser Poland Voivodeship, Poland	49.3117, 20.0436
45	ITS: PZ745203 rpoC1: PZ784251 trnH-psbA: PZ784276	*Alchemilla subglobosa* C.G.Westerl.	UGDA.0202308	Połchówko, Krokowa Commune, Puck County, Pomeranian Voivodeship, Poland	54.72966, 18.20799
46	ITS: PZ745186 matK: PZ784183 rpoC1: PZ784231 trnH-psbA: PZ784305	*Alchemilla glaucescens Wallr*	UGDA. 0270748	Park Zdrojowy, Duszniki-Zdrój, Kłodzko County, Lower Silesian Voivodeship, Poland	50.4, 16,3888

47	ITS: PZ745202 matK: PZ784216 rpoC1: PZ784256 trnH-psbA: PZ784281	*Alchemilla mollis* (Buser) Rothm.	UGDA.0109018	Chrząstawa Mała, Czernica Commune, Wrocław County, Lower Silesian Voivodeship, Poland	51.083, 17.2846
48	ITS: PZ745204 matK: PZ784188 rpoC1: PZ784248 trnH-psbA: PZ784298	*Alchemilla mollis (Buser) Rothm.*	UGDA.0202304	Gdańsk-Oliwa, Gdańsk, Pomeranian Voivodeship, Poland (R.O.D. "Leśnik" allotment gardens)	54.402674, 18.547230
49	ITS: PZ745180 matK: PZ784189 rpoC1: PZ784249 trnH-psbA: PZ784283	*Alchemilla hirsuticaulis H.Lindb.*	UGDA.0109014	Krokowa, Puck County, Pomeranian Voivodeship, Poland	54.7797, 18.1663

Supplementary Table S6. Identification of sequence labels used in the ITS NeighborNet network.

Supplementary Table S6. Identification of sequence labels used in the ITS NeighborNet network.			
Network label	**Species**	**Source**	**GenBank accession No.**
A.graci_AKC1	*Alchemilla gracilis* Opiz	This study	PZ745178
A.graci_AKC2	*Alchemilla gracilis* Opiz	This study	PZ745183
A.graci_AKC3	*Alchemilla gracilis* Opiz	This study	PZ745187
A.graci_AKC4	*Alchemilla gracilis* Opiz	This study	PZ745198
A.subcr_AKC5	*Alchemilla subcrenata* Buser	This study	PZ745193
A.subcr_AKC6	*Alchemilla subcrenata* Buser	This study	PZ745184
A.subcr_AKC7	*Alchemilla subcrenata* Buser	This study	PZ745207
A.subcr_AKC8	*Alchemilla subcrenata* Buser	This study	PZ745191
A.subcr_AKC9	*Alchemilla subcrenata* Buser	This study	PZ745182
A.glabr_AKC10	*Alchemilla glabra* Neygenf.	This study	PZ745217
A.glabr_AKC11	*Alchemilla glabra* Neygenf.	This study	PZ745215
A.glabr_AKC12	*Alchemilla glabra* Neygenf.	This study	PZ745209
A.glabr_AKC13	*Alchemilla glabra* Neygenf.	This study	PZ745216
A.glabr_AKC14	*Alchemilla glabra* Neygenf.	This study	PZ745214
A.glabr_AKC15	*Alchemilla glabra* Neygenf.	This study	PZ745208
A.glabr_AKC16	*Alchemilla glabra* Neygenf.	This study	PZ745212
A.glabr_AKC17	*Alchemilla glabra* Neygenf.	This study	PZ745211
A.glabr_AKC19	*Alchemilla glabra* Neygenf.	This study	PZ745197
A.glabr_AKC20	*Alchemilla glabra* Neygenf.	This study	PZ745213
A.glabr_AKC21	*Alchemilla glabra* Neygenf.	This study	PZ745206
A.glabr_AKC22	*Alchemilla glabra* Neygenf.	This study	PZ745210
A.glauc_AKC24	*Alchemilla glaucescens* Wallr.	This study	PZ745190
A.glauc_AKC25	*Alchemilla glaucescens* Wallr.	This study	PZ745188
A.glauc_AKC26	*Alchemilla glaucescens* Wallr.	This study	PZ745179
A.glabr_AKC27	*Alchemilla glabra* Neygenf.	This study	PZ745189

A.glauc_AKC33	*Alchemilla glaucescens* Wallr.	This study	PZ745181
A.glauc_AKC34	*Alchemilla glaucescens* Wallr.	This study	PZ745201
A.glauc_AKC35	*Alchemilla glaucescens* Wallr.	This study	PZ745194
A.glauc_AKC36	*Alchemilla glaucescens* Wallr.	This study	PZ745205
A.glauc_AKC37	*Alchemilla glaucescens* Wallr.	This study	PZ745199
A.graci_AKC38	*Alchemilla gracilis* Opiz	This study	PZ745200
A.graci_AKC39	*Alchemilla gracilis* Opiz	This study	PZ745196
A.glauc_AKC41	*Alchemilla glaucescens* Wallr.	This study	PZ745195
A.glauc_AKC42	*Alchemilla glaucescens* Wallr.	This study	PZ745185
A.graci_AKC43	*Alchemilla gracilis* Opiz	This study	PZ745192
A.subgl_AKC45	*Alchemilla subglobosa* C.G.Westerl.	This study	PZ745203
A.glauc_AKC46	*Alchemilla glaucescens* Wallr	This study	PZ745186
A.molli_AKC47	*Alchemilla mollis* (Buser) Rothm.	This study	PZ745202
A.molli_AKC48	*Alchemilla mollis* (Buser) Rothm.	This study	PZ745204
A.hirsu_AKC49	*Alchemilla hirsuticaulis* H.Lindb.	This study	PZ745180
A.molli_AJ511769	*Alchemilla mollis* (Buser) Rothm.	GenBank	AJ511769
A.abyss_EU072507	*Alchemilla abyssinica* Fresen.	GenBank	EU072507
A.alpin_EU072508	*Alchemilla alpina* L.	GenBank	EU072508
A.andri_EU072509	*Alchemilla andringitrensis* R.Vig. & De Wild.	GenBank	EU072509
A.angus_EU072510	*Alchemilla angustata* S.E.Fröhner	GenBank	EU072510
A.arani_EU072511	*Alchemilla aranica* S.E.Fröhner	GenBank	EU072511
A.argyr_EU072512	*Alchemilla argyrophylla* Oliv.	GenBank	EU072512
A.atriu_EU072513	*Alchemilla atriuscula* S.E.Fröhner	GenBank	EU072513
A.catoc_EU072514	*Alchemilla catochnoa* Rothm.	GenBank	EU072514
A.charb_EU072515	*Alchemilla charbonneliana* Buser ex Charb.	GenBank	EU072515
A.crini_EU072519	*Alchemilla crinita* Buser	GenBank	EU072519
A.crypt_EU072520	*Alchemilla cryptantha* Steud. ex A.Rich.	GenBank	EU072520
A.decum_EU072521	*Alchemilla decumbens* Buser	GenBank	EU072521
A.dewil_EU072522	*Alchemilla dewildermanii* T.C.E.Fr.	GenBank	EU072522

A.ellen_EU072523	*Alchemilla ellenbeckii* Engl.	GenBank	EU072523
A.elong_EU072524	*Alchemilla elongata* Eckl. & Zeyh.	GenBank	EU072524
A.elgon_EU072525	*Alchemilla elgonensis* Mildbr.	GenBank	EU072525
A.epips_EU072526	*Alchemilla epipsila* Juz.	GenBank	EU072526
A.fisch_EU072529	*Alchemilla fischeri* Engl.	GenBank	EU072529
A.graci_EU072532	*Alchemilla gracilipes* (Engl.) Engl.	GenBank	EU072532
A.granv_EU072533	*Alchemilla granvikii* T.C.E.Fr.	GenBank	EU072533
A.greni_EU072534	*Alchemilla grenieri* Guillot	GenBank	EU072534
A.hagen_EU072535	*Alchemilla hageniae* T.C.E.Fr.	GenBank	EU072535
A.hauma_EU072536	*Alchemilla haumanii* Rothm.	GenBank	EU072536
A.hepta_EU072537	*Alchemilla heptagona* Juz.	GenBank	EU072537
A.hilde_EU072538	*Alchemilla hildebrandtii* Engl.	GenBank	EU072538
A.hispa_EU072539	*Alchemilla hispanica* S.E.Fröhner	GenBank	EU072539
A.ilerd_EU072540	*Alchemilla ilerdensis* S.E.Fröhner	GenBank	EU072540
A.indiv_EU072542	*Alchemilla indivisa* (Formánek ex Buser) Rothm.	GenBank	EU072542
A.johns_EU072544	*Alchemilla johnstonii* Oliv.	GenBank	EU072544
A.kiwue_EU072545	*Alchemilla kiwuensis* Engl.	GenBank	EU072545
A.longa_EU072547	*Alchemilla longana* Buser	GenBank	EU072547
A.micro_EU072548	*Alchemilla microbetula* T.C.E.Fr.	GenBank	EU072548
A.minor_EU072549	*Alchemilla minor* H.Lindb.	GenBank	EU072549
A.molli_EU072550	*Alchemilla mollis* (Buser) Rothm.	GenBank	EU072550
A.monts_EU072551	*Alchemilla montserratii* S.E.Fröhner	GenBank	EU072551
A.pedat_EU072553	*Alchemilla pedata* Hochst. ex A.Rich.	GenBank	EU072553
A.penta_EU072554	*Alchemilla pentaphyllea* L.	GenBank	EU072554
A.plica_EU072555	*Alchemilla plicata* Buser	GenBank	EU072555
A.rocca_EU072557	*Alchemilla roccatii* Cortesi	GenBank	EU072557
A.ruten_EU072558	*Alchemilla rutenbergii* O.Hoffm.	GenBank	EU072558
A.schiz_EU072560	*Alchemilla schizophylla* Baker	GenBank	EU072560
A.schmi_EU072561	*Alchemilla schmidelyana* Buser	GenBank	EU072561

A.glaci_EU072562	*Alchemilla glacialis* Buser	GenBank	EU072562
A.stuhl_EU072564	*Alchemilla stuhlmannii* Engl.	GenBank	EU072564
A.subni_EU072565	*Alchemilla subnivalis* Baker f.	GenBank	EU072565
A.subse_EU072566	*Alchemilla subsericea* Reut.	GenBank	EU072566
A.tener_EU072567	*Alchemilla tenerifolia* S.E.Fröhner	GenBank	EU072567
A.tenui_EU072568	*Alchemilla tenuis* Buser	GenBank	EU072568
A.trans_EU072569	*Alchemilla transiens* (Buser) Buser	GenBank	EU072569
A.triph_EU072570	*Alchemilla triphylla* Rothm.	GenBank	EU072570
A.volke_EU072572	*Alchemilla volkensii* Engl.	GenBank	EU072572
A.vulga_EU072573	*Alchemilla vulgaris* L.	GenBank	EU072573
A.cf_sub_EU072575	*Alchemilla cf subnivalis* Baker f.	GenBank	EU072575
A.aphan_EU072582	*Alchemilla aphanoide*s Mutis ex L.f.	GenBank	EU072582
A.diplo_EU072583	*Alchemilla diplophylla* Diels	GenBank	EU072583
A.hispi_EU072584	*Alchemilla hispidula* L.M.Perry	GenBank	EU072584
A.holos_EU072585	*Alchemilla holosericea* L.M.Perry	GenBank	EU072585
A.nival_EU072587	*Alchemilla nivalis* Kunth	GenBank	EU072587
A.orbic_EU072588	*Alchemilla orbiculata* Ruiz & Pav.	GenBank	EU072588
A.pinna_EU072589	*Alchemilla pinnata* Ruiz & Pav.	GenBank	EU072589
A.vulca_EU072591	*Alchemilla vulcanica* Cham. & Schltdl.	GenBank	EU072591
A.crypt_FJ356153	*Alchemilla cryptantha* Steud. ex A.Rich.	GenBank	FJ356153
A.galio_HM453903	*Alchemilla galioides* Benth.	GenBank	HM453903
A.hispi_HM453904	*Alchemilla hispidula* L.M.Perry	GenBank	HM453904
A.spruc_HM453905	*Alchemilla sprucei* L.M.Perry	GenBank	HM453905
A.nival_HM453906	*Alchemilla nivalis* Kunth	GenBank	HM453906
A.nival_HM453907	*Alchemilla nivalis* Kunth	GenBank	HM453907
A.hispi_HM453908	*Alchemilla hispidula* L.M.Perry	GenBank	HM453908
A.polyl_HM453910	*Alchemilla polylepis* Wedd.	GenBank	HM453910
A.polyl_HM453911	*Alchemilla polylepis* Wedd.	GenBank	HM453911
A.verti_HM453912	*Alchemilla verticillata* Fielding & Gardner	GenBank	HM453912

A.procu_HM453913	*Alchemilla procumbens* Rose	GenBank	HM453913
A.hirta_HM453914	*Alchemilla hirta* (L.M.Perry) Rothm.	GenBank	HM453914
A.andin_HM453915	*Alchemilla andina* (L.M.Perry) J.F.Macbr.	GenBank	HM453915
A.vulca_HM453916	*Alchemilla vulcanica* Cham. & Schltdl.	GenBank	HM453916
A.vulca_HM453917	*Alchemilla vulcanica* Cham. & Schltdl.	GenBank	HM453917
A.hirta_HM453918	*Alchemilla hirta* (L.M.Perry) Rothm.	GenBank	HM453918
A.james_HM453919	*Alchemilla jamesonii* L.M.Perry	GenBank	HM453919
A.aphan_HM453920	*Alchemilla aphanoides* Mutis ex L.f.	GenBank	HM453920
A.aphan_HM453921	*Alchemilla aphanoides* Mutis ex L.f.	GenBank	HM453921
A.aphan_HM453922	*Alchemilla aphanoides* Mutis ex L.f.	GenBank	HM453922
A.aphan_HM453923	*Alchemilla aphanoides* Mutis ex L.f.	GenBank	HM453923
A.ocrea_HM453924	*Alchemilla ocreata* Donn.Sm.	GenBank	HM453924
A.pecti_HM453926	*Alchemilla pectinata* Kunth	GenBank	HM453926
A.fulve_HM453927	*Alchemilla fulvescens* (L.M.Perry) Rothm.	GenBank	HM453927
A.galio_HM453928	*Alchemilla galioides* Benth.	GenBank	HM453928
A.orbic_HM453929	*Alchemilla orbiculata* Ruiz & Pav.	GenBank	HM453929
A.orbic_HM453930	*Alchemilla orbiculata* Ruiz & Pav.	GenBank	HM453930
A.james_HM453931	*Alchemilla jamesonii* L.M.Perry	GenBank	HM453931
A.pecti_HM453932	*Alchemilla pectinata* Kunth	GenBank	HM453932
A.rupes_HM453933	*Alchemilla rupestris* Kunth	GenBank	HM453933
A.rupes_HM453934	*Alchemilla rupestris* Kunth	GenBank	HM453934
A.mando_HM45393[illegible]	*Alchemilla mandoniana* Wedd.	GenBank	HM453935
A.andin_HM453936	*Alchemilla andina* (L.M.Perry) J.F.Macbr.	GenBank	HM453936
A.mando_HM45393[illegible]	*Alchemilla mandoniana* Wedd.	GenBank	HM453937
A.mando_HM45393[illegible]	*Alchemilla mandoniana* Wedd.	GenBank	HM453939
A.pinna_HM453940	*Alchemilla pinnata* Ruiz & Pav.	GenBank	HM453940
A.pinna_HM453941	*Alchemilla pinnata* Ruiz & Pav.	GenBank	HM453941
A.tanac_HM453942	*Alchemilla tanacetifolia* Rothm.	GenBank	HM453942
A.diplo_HM453943	*Alchemilla diplophylla* Diels	GenBank	HM453943

A.diplo_HM453944	*Alchemilla diplophylla* Diels	GenBank	HM453944
A.holos_HM453946	*Alchemilla holosericea* L.M.Perry	GenBank	HM453946
A.holos_HM453947	*Alchemilla holosericea* L.M.Perry	GenBank	HM453947
A.abyss_KT321980	*Alchemilla abyssinica* Fresen.	GenBank	KT321980
A.andri_KT321981	*Alchemilla andringitrensis* R.Vig. & De Wild.	GenBank	KT321981
A.argyr_KT321982	*Alchemilla argyrophylla* Oliv.	GenBank	KT321982
A.fisch_KT321986	*Alchemilla fischeri* Engl.	GenBank	KT321986
A.graci_KT321987	Alchemilla gracilipes (Engl.) Engl.	GenBank	KT321987
A.hauma_KT321988	*Alchemilla haumanii* Rothm.	GenBank	KT321988
A.johns_KT321989	*Alchemilla johnstonii* Oliv.	GenBank	KT321989
A.kiwue_KT321990	*Alchemilla kiwuensis* Engl.	GenBank	KT321990
A.micro_KT321991	*Alchemilla microbetula* T.C.E.Fr.	GenBank	KT321991
A.ruten_KT321992	*Alchemilla rutenbergii* O.Hoffm.	GenBank	KT321992
A.rothi_KT321994	*Alchemilla rothii* Oliv.	GenBank	KT321994
A.procu_KY351937	*Alchemilla procumbens var andina* L.M.Perry	GenBank	KY351937
A.procu_KY351938	*Alchemilla procumbens var andina* L.M.Perry	GenBank	KY351938
A.aphan_KY351940	*Alchemilla aphanoides* Mutis ex L.f.	GenBank	KY351940
A.aphan_KY351943	*Alchemilla aphanoides* Mutis ex L.f.	GenBank	KY351943
A.aphan_KY351944	*Alchemilla aphanoides* Mutis ex L.f.	GenBank	KY351944
A.aphan_KY351945	*Alchemilla aphanoides* Mutis ex L.f.	GenBank	KY351945
A.aphan_KY351946	*Alchemilla aphanoides* Mutis ex L.f.	GenBank	KY351946
A.aphan_KY351947	*Alchemilla aphanoides* Mutis ex L.f.	GenBank	KY351947
A.diplo_KY351953	*Alchemilla diplophylla* Diels	GenBank	KY351953
A.diplo_KY351954	*Alchemilla diplophylla* Diels	GenBank	KY351954
A.diplo_KY351955	*Alchemilla diplophylla* Diels	GenBank	KY351955
A.fulve_KY351962	*Alchemilla fulvescens* (L.M.Perry) Rothm.	GenBank	KY351962
A.fulve_KY351963	*Alchemilla fulvescens* (L.M.Perry) Rothm.	GenBank	KY351963
A.fulve_KY351964	*Alchemilla fulvescens* (L.M.Perry) Rothm.	GenBank	KY351964
A.galio_KY351965	*Alchemilla galioides* Benth.	GenBank	KY351965

A.hirta_KY351966	*Alchemilla hirta* (L.M.Perry) Rothm.	GenBank	KY351966
A.hirta_KY351967	*Alchemilla hirta* (L.M.Perry) Rothm.	GenBank	KY351967
A.hispi_KY351968	*Alchemilla hispidula* L.M.Perry	GenBank	KY351968
A.hispi_KY351969	*Alchemilla hispidula* L.M.Perry	GenBank	KY351969
A.hispi_KY351970	*Alchemilla hispidula* L.M.Perry	GenBank	KY351970
A.holos_KY351972	*Alchemilla holosericea* L.M.Perry	GenBank	KY351972
A.holos_KY351973	*Alchemilla holosericea* L.M.Perry	GenBank	KY351973
A.nival_KY351983	*Alchemilla nivalis* Kunth	GenBank	KY351983
A.nival_KY351984	*Alchemilla nivalis* Kunth	GenBank	KY351984
A.orbic_KY351985	*Alchemilla orbiculata* Ruiz & Pav.	GenBank	KY351985
A.orbic_KY351987	*Alchemilla orbiculata* Ruiz & Pav.	GenBank	KY351987
A.pecti_KY351988	*Alchemilla pectinata* Kunth	GenBank	KY351988
A.pecti_KY351990	*Alchemilla pectinata* Kunth	GenBank	KY351990
A.pecti_KY351991	*Alchemilla pectinata* Kunth	GenBank	KY351991
A.pecti_KY351992	*Alchemilla pectinata* Kunth	GenBank	KY351992
A.pinna_KY351995	*Alchemilla pinnata* Ruiz & Pav.	GenBank	KY351995
A.pinna_KY351997	*Alchemilla pinnata* Ruiz & Pav.	GenBank	KY351997
A.pinna_KY351998	*Alchemilla pinnata* Ruiz & Pav.	GenBank	KY351998
A.pinna_KY351999	*Alchemilla pinnata* Ruiz & Pav.	GenBank	KY351999
A.polyl_KY352000	*Alchemilla polylepis* Wedd.	GenBank	KY352000
A.procu_KY352003	*Alchemilla procumbens* Rose	GenBank	KY352003
A.procu_KY352004	*Alchemilla procumbens* Rose	GenBank	KY352004
A.rupes_KY352008	*Alchemilla rupestris* Kunth	GenBank	KY352008
A.rupes_KY352009	*Alchemilla rupestris* Kunth	GenBank	KY352009
A.rupes_KY352010	*Alchemilla rupestris* Kunth	GenBank	KY352010
A.rupes_KY352011	*Alchemilla rupestris* Kunth	GenBank	KY352011
A.spruc_KY352017	*Alchemilla sprucei* L.M.Perry	GenBank	KY352017
A.tanac_KY352020	*Alchemilla tanacetifolia* Rothm.	GenBank	KY352020
A.tanac_KY352021	*Alchemilla tanacetifolia* Rothm.	GenBank	KY352021

A.vulca_KY352028	*Alchemilla vulcanica* Cham. & Schltdl.	GenBank	KY352028
A.vulca_KY352029	*Alchemilla vulcanica* Cham. & Schltdl.	GenBank	KY352029
A.vulca_KY352030	*Alchemilla vulcanica* Cham. & Schltdl.	GenBank	KY352030
A.vulca_KY352031	*Alchemilla vulcanica* Cham. & Schltdl.	GenBank	KY352031
A.japon_MH809009	*Alchemilla japonica* Nakai & H.Hara	GenBank	MH809009
A.cymat_MN663001	*Alchemilla cymatophylla* Juz.	GenBank	MN663001
A.murbe_MN663002	*Alchemilla murbeckiana* Buser	GenBank	MN663002
A.chang_OM184269	*Alchemilla changaica* V.N.Tikhom.	GenBank	OM184269
A.pavlo_OM200033	*Alchemilla pavlovii* Juz.	GenBank	OM200033
A.guban_OM201308	*Alchemilla gubanovii* V.N.Tikhom.	GenBank	OM201308
A.cymat_OP784981	*Alchemilla cymatophylla* Juz.	GenBank	OP784981
A.chang_OP997636	*Alchemilla changaica* V.N.Tikhom.	GenBank	OP997636
A.guban_OP998101	*Alchemilla gubanovii* V.N.Tikhom.	GenBank	OP998101
A.chang_OP998103	*Alchemilla circularis* Juz.	GenBank	OP998103
A.cyrto_OP998104	*Alchemilla cyrtopleura* Juz.	GenBank	OP998104
A.pavlo_OP998212	*Alchemilla pavlovii* Juz.	GenBank	OP998212
A.vulga_OR660184	*Alchemilla vulgaris* L.	GenBank	OR660184

Supplementary Table S7. Genome size of the investigated *Alchemilla* accessions

Supplementary Table S7. Genome size of the investigated *Alchemilla* accessions

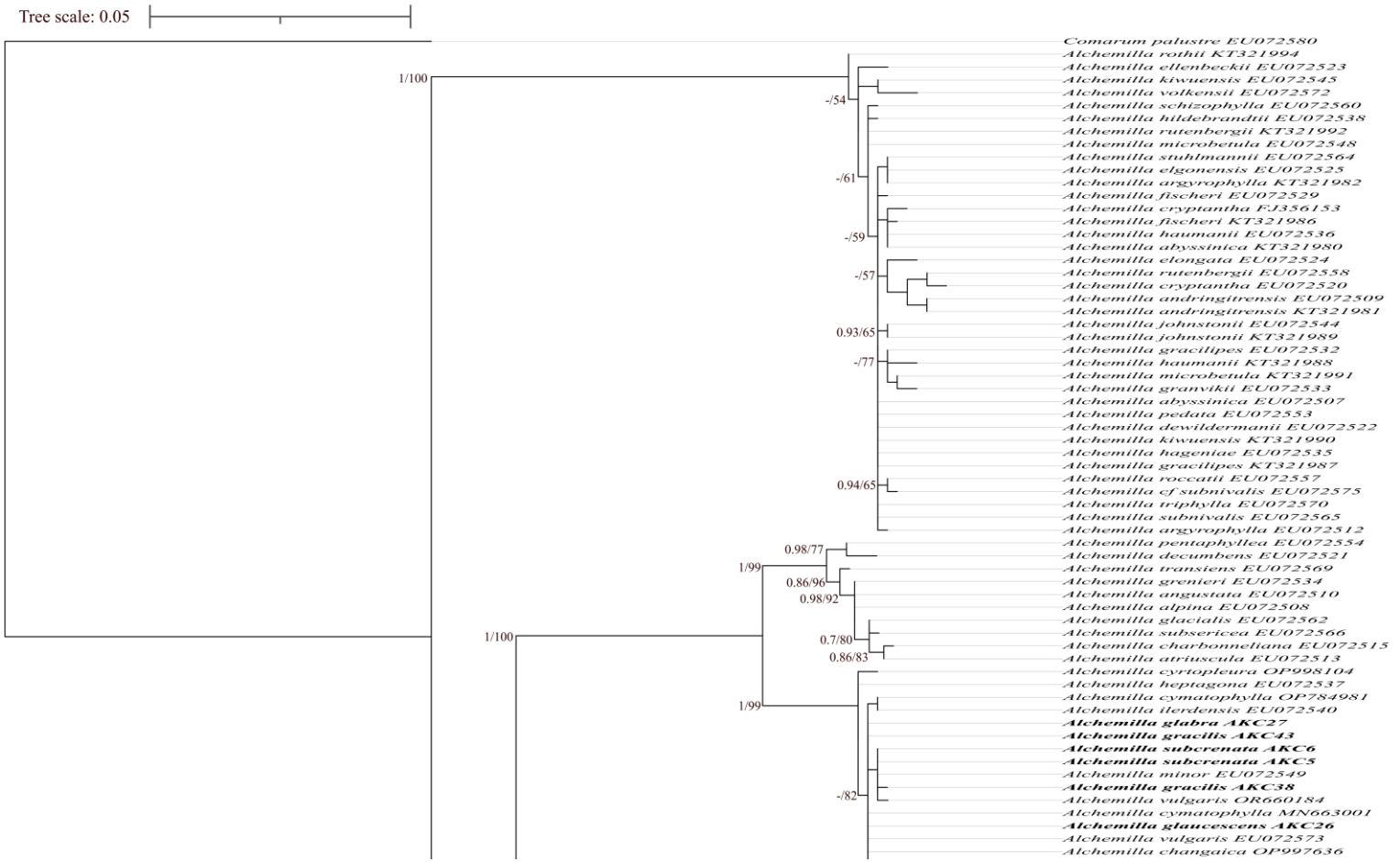
Sample ID group (S3)	Molecular label (AKC)	Species	Collection locality	DNA content (2C)		CV (%)
				pg ± SD	Mbp	
Alchemilla_1	AKC1-4	*Alchemilla gracilis* Opiz	Wirty, near Arboretum Wirty, Pomeranian Voivodeship, Poland	3.67±0.07 ab	3589	5.06
Alchemilla_2	AKC5-9	*Alchemilla subcrenata* Buser	Mrzezino, south of the village, north of the Reda River, Puck County, Pomeranian Voivodeship, Poland	3.69±0.07 ab	3609	5.42
Alchemilla_3	AKC10-17	*Alchemilla glabra* Neygenf.	Wejherowo, Wejherowo County, Pomeranian Voivodeship, Poland	3.56±0.11 ab	3482	5.68
Alchemilla_4	AKC18-23	*Alchemilla glabra* Neygenf.	Przetoczyno area, Szemud Commune, Wejherowo County, Pomeranian Voivodeship, Poland	3.56±0.03 ab	3482	5.75
Alchemilla_5	AKC24-26	*Alchemilla glaucescens* Wallr.	Rąb, Otalżyńska Street, Przodkowo Commune, Kartuzy County, Pomeranian Voivodeship, Poland	3.72±0.05 a*	3638	6.11
Alchemilla_6	AKC30-32	*Alchemilla glaucescens* Wallr.	Kochanowo area, near the Góra Forest District headquarters, Luzino Commune, Wejherowo County,	3.63±0.07 ab	3550	4.40
Alchemilla_7	AKC29	*Alchemilla glabra* Neygenf.	Ustarbowo, Wejherowo Commune, Wejherowo County, Pomeranian Voivodeship, Poland	3.63±0.05 ab	3550	4.40
Alchemilla_8	AKC33-37	*Alchemilla glaucescens* Wallr.	Osowa district, city of Gdańsk, Pomeranian Voivodeship, Poland	3.71±0.09 a	3628	4.95
Alchemilla_9	AKC41-42	*Alchemilla glaucescens* Wallr.	Gile (near Stasiki), Zakopane vicinity, Tatra County, Lesser Poland Voivodeship, Poland	3.69±0.04 ab	3609	5.36
Alchemilla_10	AKC38-39, AKC43	*Alchemilla gracilis* Opiz	Witów, Tatra County, Lesser Poland Voivodeship, Poland	3.60±0.07 ab	3520	5.74
Alchemilla_11	AKC40, AKC44	*Alchemilla monticola* Opiz	Murzasichle vicinity (near Zakopane), Tatra County, Lesser Poland Voivodeship, Poland	3.58±0.08 ab	3501	5.55
Alchemilla_12	AKC45	*Alchemilla subglobosa* C.G.Westerl.	Połchówko, Krokowa Commune, Puck County, Pomeranian Voivodeship, Poland	3.56±0.04 ab	3482	5.86
Alchemilla_13	–	*Alchemilla glaucescens* Wallr.	Henrykowo, Orneta Commune, Lidzbark County, Warmian-Masurian Voivodeship, Poland	3.63±0.02 ab	3550	5.03
Alchemilla_14	AKC47	*Alchemilla mollis* (Buser) Rothm.	Chrząstawa Mała, Czernica Commune, Wrocław County, Lower Silesian Voivodeship, Poland	3.69±0.31 ab	3609	4.84
Alchemilla_15	AKC48	*Alchemilla mollis* (Buser) Rothm.	Gdańsk-Oliwa, Gdańsk, Pomeranian Voivodeship, Poland (R.O.D. "Leśnik" allotment gardens)	3.58±0.03 ab	3501	5.39
Alchemilla_16	AKC49	*Alchemilla hirsuticaulis* H.Lindb.	Krokowa, Puck County, Pomeranian Voivodeship, Poland	3.52±0.06 b	3443	5.35

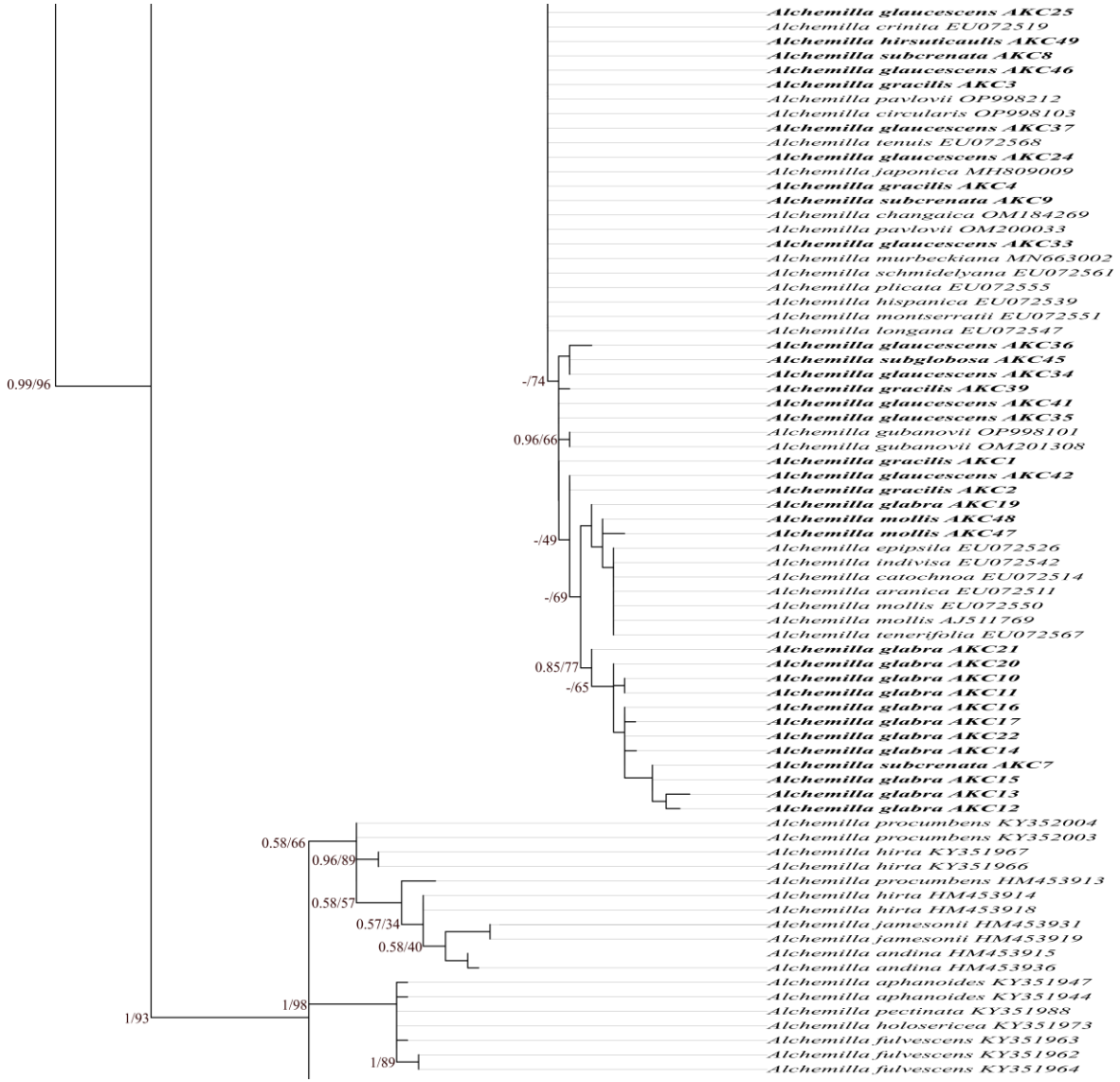
** Values followed by the same letter are not significantly different at $p < 0.05$ (Newman–Keuls test).*

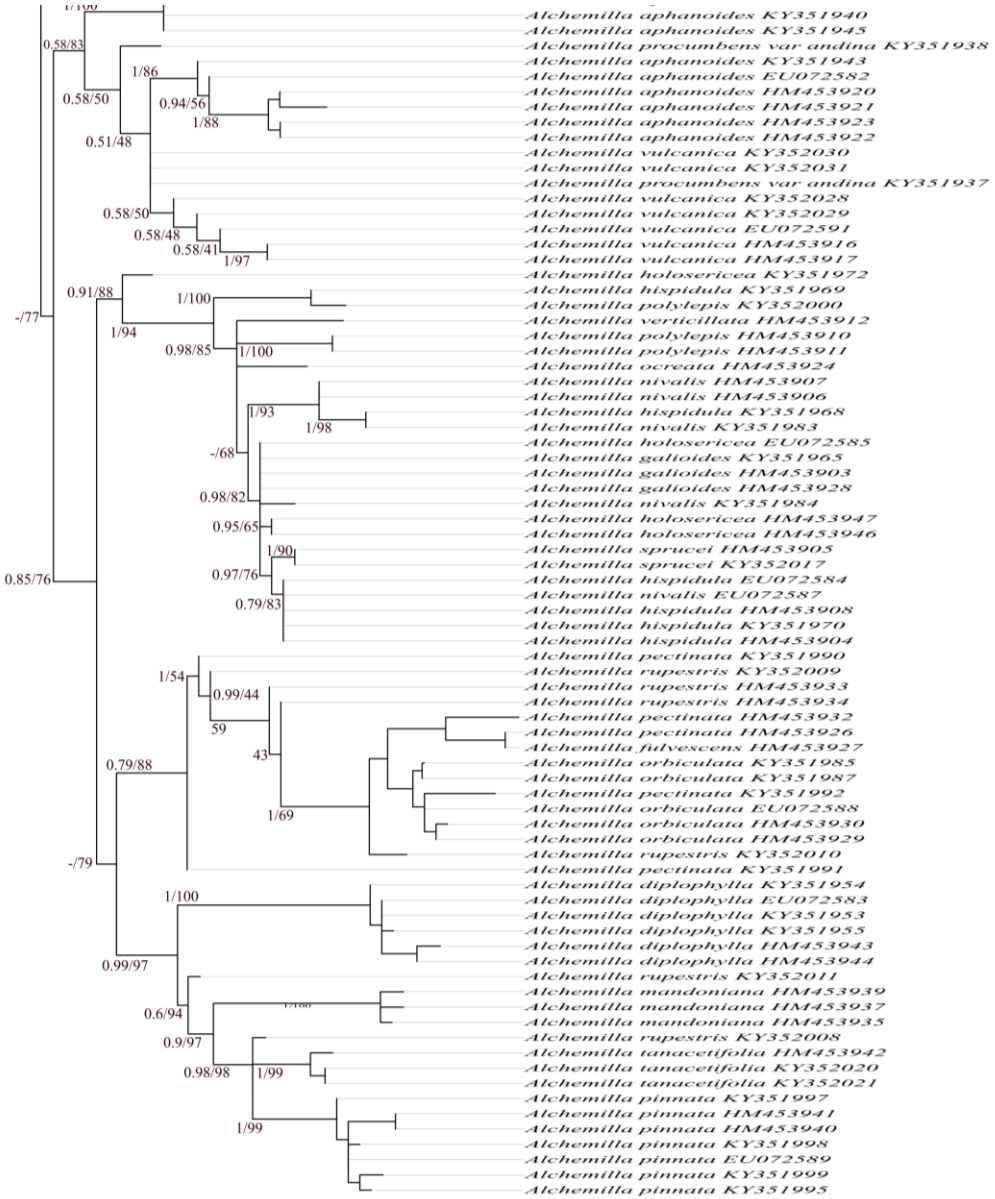
Supplementary Table S8. Collapsed species and their geographic distributions based on the ITS phylogeny.

Supplementary Table S8. Collapsed species and their geographic distributions based on the ITS phylogeny.		
Clade	**Species**	**Geographic distribution**
A	*A. abyssinica*, *A. andringitrensis*, *A. argyrophylla*, *A.* cf *subnivalis*, *A. cryptantha*, *A. dewildermanii*, *A. elgonensis*, *A. ellenbeckii*, *A. elongata*, *A. fischeri*, *A. gracilipes*, *A. granvikii*, *A. hageniae*, *A. haumanii*, *A. hildebrandtii*, *A. johnstonii*, *A. kiwuensis*, *A. microbetula*, *A. pedata*, *A. roccatii*, *A. rothii*, *A. rutenbergii*, *A. schizophylla*, *A. stuhlmannii*, *A. subnivalis*, *A. triphylla*, *A. volkensii*.	Africa
C1	*A. alpina*, *A. angustata*, *A. atriuscula*, *A. charbonneliana*, *A. decumbens*, *A. glacialis*, *A. grenieri*, *A. subsericea*, *A. transiens*	Eurasia
D	*A. andina*, *A. aphanoides*, *A. diplophylla*, *A. fulvescens*, *A. galioides*, *A. hirta*, *A. hispidula*, *A. holosericea*, *A. jamesonii*, *A. mandoniana*, *A. nivalis*, *A. ocreata*, *A. orbiculata*, *A. pectinata*, *A. pinnata*, *A. polylepis*, *A. procumbens*, *A. procumbens* var *andina*, *A. rupestris*, *A. sprucei*, *A. tanacetifolia*, *A. verticillata*, *A. vulcanica*.	America

Supplementary Figure S1. Maximum-likelihood phylogeny of *Alchemilla* inferred from the ITS dataset. Values at nodes represent bootstrap support (BS) and Bayesian posterior probabilities (PP), respectively.

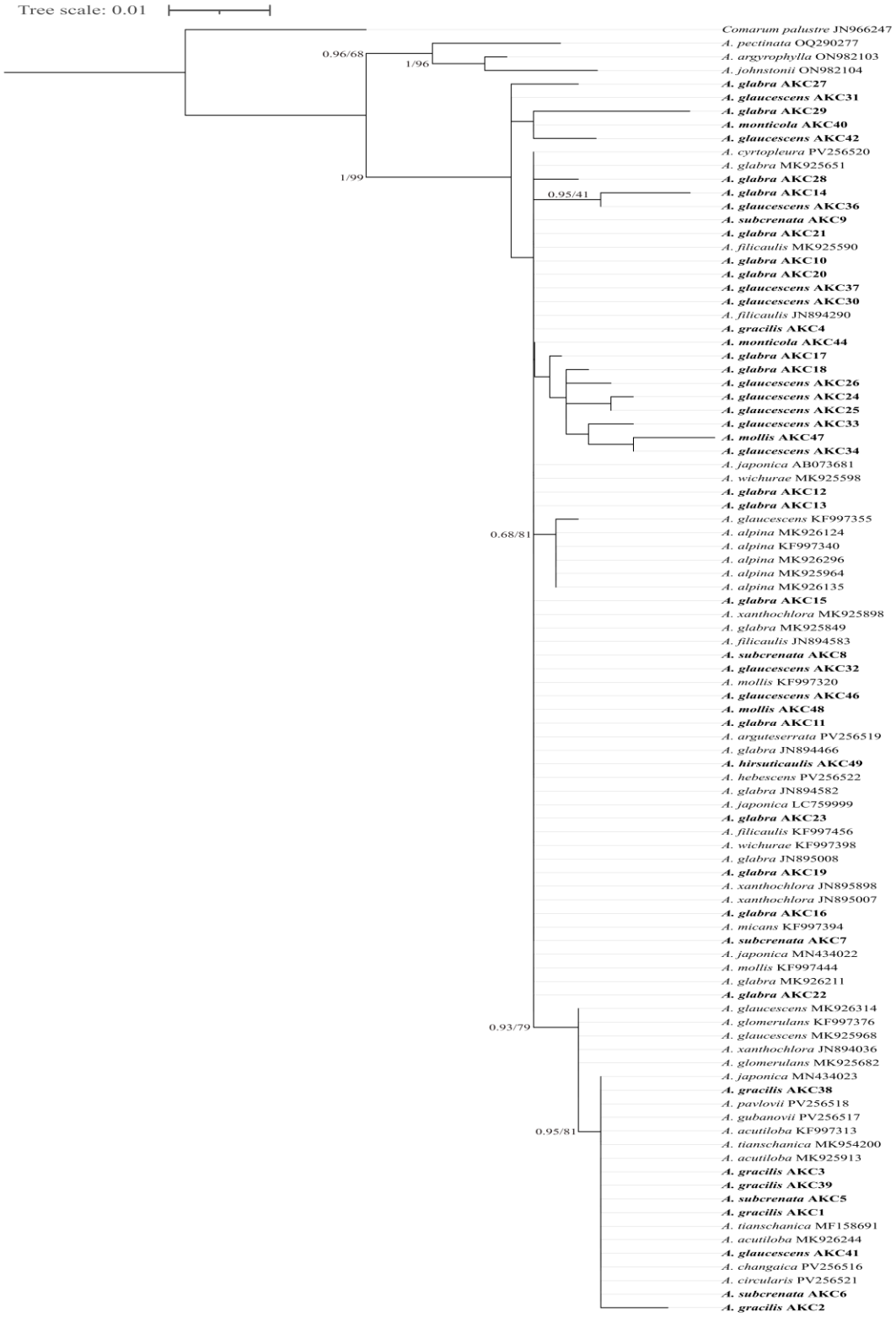



Alchemilla glaucescens AKC25
Alchemilla crinita EU072519
Alchemilla hirsuticaulis AKC49
Alchemilla subcrenata AKC8
Alchemilla glaucescens AKC46
Alchemilla gracilis AKC3
Alchemilla pavlovii OP998212
Alchemilla circularis OP998103
Alchemilla glaucescens AKC37
Alchemilla tenuis EU072568
Alchemilla glaucescens AKC24
Alchemilla japonica MH809009
Alchemilla gracilis AKC4
Alchemilla subcrenata AKC9
Alchemilla changaica OM184269
Alchemilla pavlovii OM200033
Alchemilla glaucescens AKC33
Alchemilla murbeckiana MN663002
Alchemilla schmidelyana EU072561
Alchemilla plicata EU072555
Alchemilla hispanica EU072539
Alchemilla montserratii EU072551
Alchemilla longana EU072547
Alchemilla glaucescens AKC36
Alchemilla subglobosa AKC45
Alchemilla glaucescens AKC34
Alchemilla gracilis AKC39
Alchemilla glaucescens AKC41
Alchemilla glaucescens AKC35
Alchemilla gubanovii OP998101
Alchemilla gubanovii OM201308
Alchemilla gracilis AKC1
Alchemilla glaucescens AKC42
Alchemilla gracilis AKC2
Alchemilla glabra AKC19
Alchemilla mollis AKC48
Alchemilla mollis AKC47
Alchemilla epipsila EU072526
Alchemilla indivisa EU072542
Alchemilla catochnoa EU072514
Alchemilla aranica EU072511
Alchemilla mollis EU072550
Alchemilla mollis AJ511769
Alchemilla tenerifolia EU072567
Alchemilla glabra AKC21
Alchemilla glabra AKC20
Alchemilla glabra AKC10
Alchemilla glabra AKC11
Alchemilla glabra AKC16
Alchemilla glabra AKC17
Alchemilla glabra AKC22
Alchemilla glabra AKC14
Alchemilla subcrenata AKC7
Alchemilla glabra AKC15
Alchemilla glabra AKC13
Alchemilla glabra AKC12
Alchemilla procumbens KY352004
Alchemilla procumbens KY352003
Alchemilla hirta KY351967
Alchemilla hirta KY351966
Alchemilla procumbens HM453913
Alchemilla hirta HM453914
Alchemilla hirta HM453918
Alchemilla jamesonii HM453931
Alchemilla jamesonii HM453919
Alchemilla andina HM453915
Alchemilla andina HM453936
Alchemilla aphanoides KY351947
Alchemilla aphanoides KY351944
Alchemilla pectinata KY351988
Alchemilla holosericea KY351973
Alchemilla fulvescens KY351963
Alchemilla fulvescens KY351962
Alchemilla fulvescens KY351964
0.99/96
-/74
0.96/66
-/49
-/69
0.85/77
-/65
0.58/66
0.96/89
0.58/57
0.57/34
0.58/40
1/98
1/93
1/89



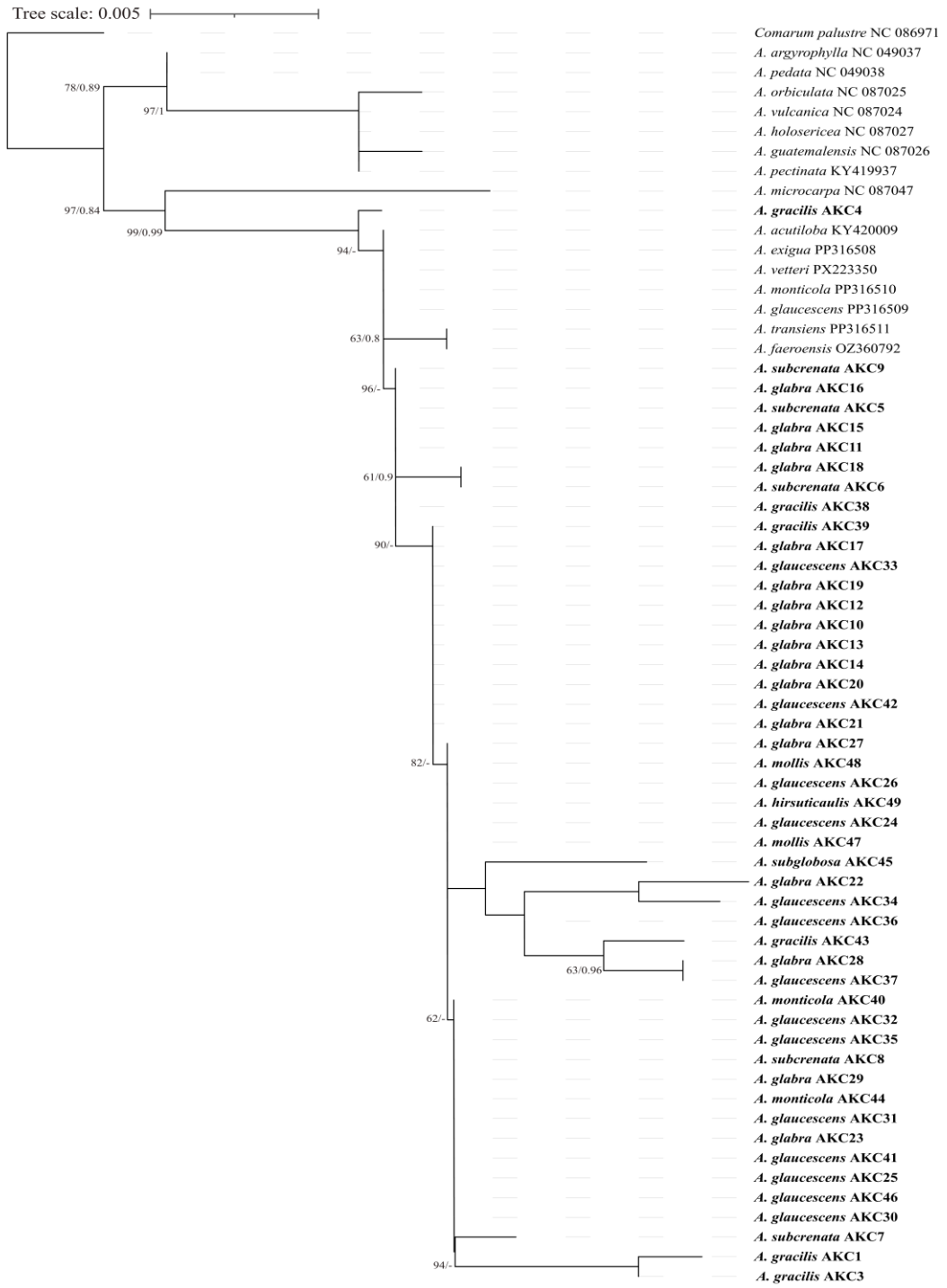
Supplementary Figure S1. Maximum-likelihood phylogeny of *Alchemilla* inferred from the ITS dataset. Values at nodes represent bootstrap support (BS) and Bayesian posterior probabilities (PP), respectively.

Supplementary Figure S2. Maximum-likelihood phylogeny of *Alchemilla* inferred from the *matK* dataset. Values at nodes represent bootstrap support (BS) and Bayesian posterior probabilities (PP), respectively.



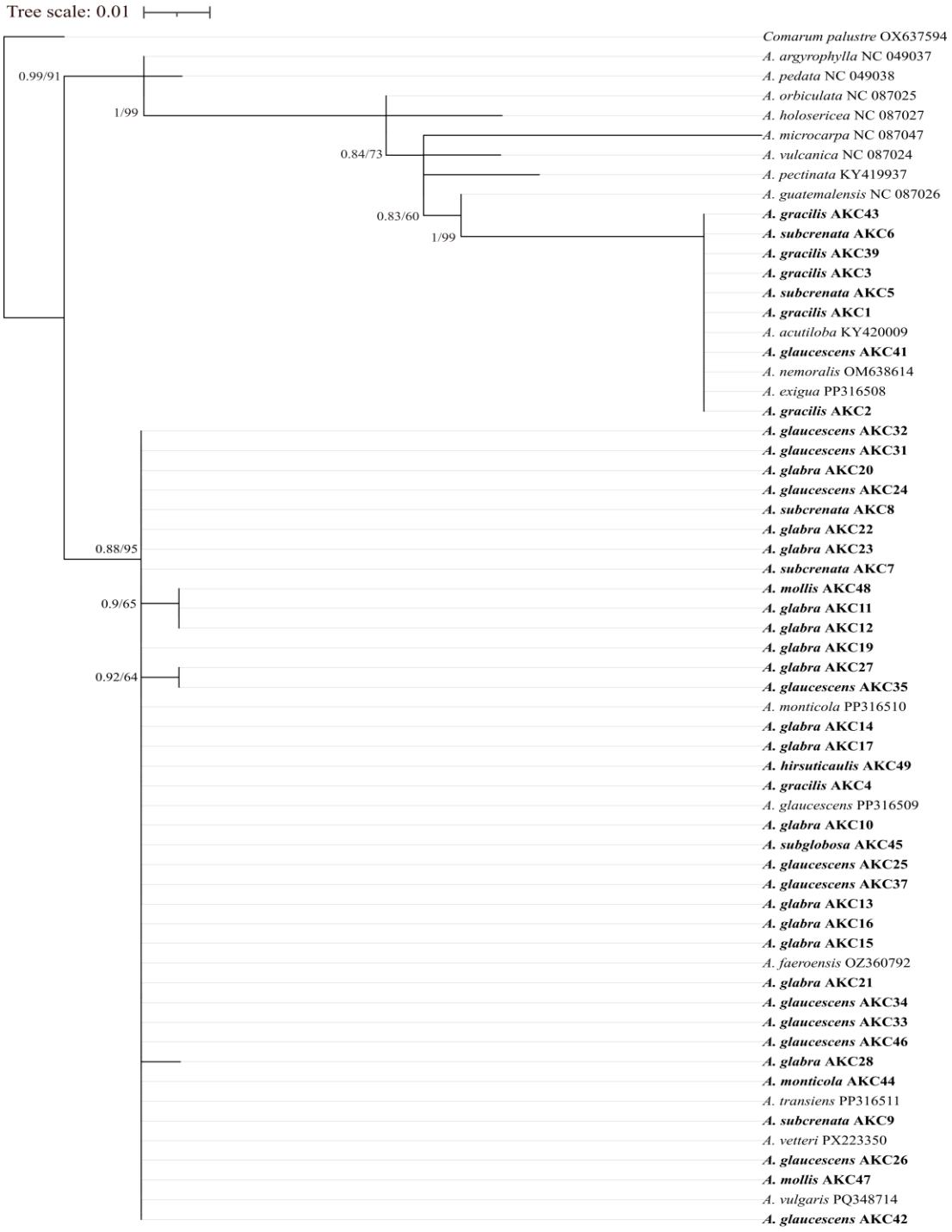
Supplementary Figure S2. Maximum-likelihood phylogeny of *Alchemilla* inferred from the *matK* dataset. Values at nodes represent bootstrap support (BS) and Bayesian posterior probabilities (PP), respectively.

Supplementary Figure S3. Maximum-likelihood phylogeny of *Alchemilla* inferred from the *rpoC1* dataset. Values at nodes represent bootstrap support (BS) and Bayesian posterior probabilities (PP), respectively.



Supplementary Figure S3. Maximum-likelihood phylogeny of *Alchemilla* inferred from the *rpoC1* dataset. Values at nodes represent bootstrap support (BS) and Bayesian posterior probabilities (PP), respectively.

Supplementary Figure S4. Maximum-likelihood phylogeny of *Alchemilla* inferred from the *trnH-psbA* dataset. Values at nodes represent bootstrap support (BS) and Bayesian posterior probabilities (PP), respectively.



Supplementary Figure S4. Maximum-likelihood phylogeny of *Alchemilla* inferred from the *trnH-psbA* dataset. Values at nodes represent bootstrap support (BS) and Bayesian posterior probabilities (PP), respectively.

11. Praca nr 3:

Can leaf morphometry support species identification in *Alchemilla*? Evidence from digitised European herbarium specimens

Adrianna M. Kosiróg-Ceynowa[1], Sławomir Nowak[1], Julia Jaskólska[1], Dariusz L. Szlachetko[1]

[1] University of Gdańsk, Faculty of Biology, Department of Plant Taxonomy and Nature Conservation, Wita Stwosza 59, 80-308 Gdańsk, Poland

Corresponding author: Sławomir Nowak (slawomir.nowak@ug.edu.pl)

Abstract

Digitized herbarium collections provide extensive material for quantitative morphological studies, but the taxonomic reliability of identifications based on individual organs remains uncertain in morphologically complex groups. We evaluated whether leaf shape can support species-level differentiation and identification in selected European taxa of *Alchemilla*. The dataset comprised 742 leaves representing 514 herbarium specimens, including 491 specimens assigned on their labels to 12 species and 23 identified only as *Alchemilla* sp. Leaf outlines were analysed using elliptic Fourier descriptors, principal component analysis, conventional shape indices, PERMANOVA, non-metric multidimensional scaling, and hierarchical clustering. The first two principal components explained 53.93% of total outline variation but showed extensive overlap among taxa. PERMANOVA, restricted to 476 specimens representing seven adequately sampled species, detected significant differences in multivariate leaf morphology; however, species identity explained only 6.7% of the total variation. Twelve of 21 pairwise comparisons remained significant after correction for multiple testing, while PERMDISP detected no significant differences in within-species dispersion. NMDS likewise showed extensive overlap among taxa. Hierarchical clustering of all 514 specimens recovered two phenotypic clusters comprising 446 and 68 specimens, but neither corresponded to taxonomic boundaries. Although 22 of the 23 unidentified specimens were assigned to the larger cluster, that cluster contained representatives of all 12 named species and therefore did

not support more precise identification. Leaf morphometry effectively quantified phenotypic variation but had limited standalone diagnostic value in the examined *Alchemilla* taxa. Reliable identification requires taxonomically verified reference material and integration of additional vegetative and reproductive characters.

Key words: *Alchemilla*; elliptic Fourier descriptors; herbarium digitisation; leaf morphometry; leaf shape; species identification

Introduction

The ongoing digitisation of herbarium collections has substantially increased their accessibility and research potential. The digitisation of herbarium specimens has increased the efficiency of taxonomic research (Harris and Marsico 2017). Scanned herbarium specimens provide high-resolution images that can be used in taxonomic, morphological, and morphometric studies (Heberling 2022). These resources facilitate analyses of large datasets assembled across collections and geographical regions without requiring direct access to the original material (Nelson and Ellis 2019). Although digitisation and access to research material are constantly improving, important limitations remain. Many specimens remain unidentified or are identified only to family or genus level, whereas others retain outdated or potentially incorrect identifications requiring specialist revision (Goodwin et al. 2015; Aceae et al. 2026). The shortage of taxonomic expertise further limits the capacity of institutions to revise the growing number of digitised specimens (Rabeler et al. 2019; Engel et al. 2021; Hollister et al. 2025). Consequently, although we now have access to vast digital databases and individual specimens, this does not necessarily mean that their taxonomic information has received sufficient expert verification. The growing availability of digitised collections therefore creates both an opportunity to develop quantitative tools for specimen assessment and a need to determine how reliably such tools reproduce existing herbarium identifications.

The genus *Alchemilla* L. (Rosaceae) provides a particularly suitable example of these taxonomic challenges. Species identification within *Alchemilla* can be particularly challenging, because of subtle and overlapping morphological differences and the occurrence of numerous apomictic microspecies within the genus

(Hayirlioglu-Ayaz and Inceer 2006; Pihu et al. 2009; Rono et al. 2020). Individual taxa are generally distinguished using combinations of vegetative and reproductive characters, whereas single characters may be variable or shared among several species (Sepp and Paal 1998). This problem is particularly significant among European taxa traditionally associated with the broadly defined *Alchemilla vulgaris* aggregate, many of which exhibit considerable overlap in morphological characters (Sepp and Paal 1998; Pihu et al. 2009). However, the circumscription of this aggregate differs among taxonomic treatments, and some morphologically similar taxa are currently assigned to adjacent groups or sections. As many species differ only in subtle combinations of morphological characters, their identification can be difficult, particularly when based exclusively on digitised images of herbarium specimens. Quantitative analysis of leaf shape may therefore provide a complementary approach for assessing morphological variation and determining whether visually similar taxa can be objectively distinguished.

In this context, morphometry provides a quantitative approach to describing and analysing the shape, size, and form of biological structures (Cope et al. 2012). It is widely applied in taxonomy, systematics, developmental biology, and plant breeding. In plant taxonomy, digital morphometry enables variation in structures such as leaves, flowers, and fruits to be described objectively and compared across large specimen datasets. Digitised herbarium collections are particularly suitable for such analyses because they provide access to material collected over broad geographical areas and long periods of time. Compared with traditional approaches based mainly on manual measurements, digital morphometry enables morphological variation to be assessed more efficiently and in a quantitative and reproducible manner. Morphometric analyses can support species identification and delimitation, including the assessment of geographical range boundaries (Wilkin 1999; Du et al. 2006; Gage and Wilkin 2008), investigations of developmental variation within species (Chitwood et al. 2016), and studies of environmental and climatic effects on plant morphology, particularly leaf shape and size (Royer 2005; Cope et al. 2012; Klein and Svoboda 2017). Leaves are particularly well suited to image-based morphometric analyses, as their two-dimensional outline can be readily digitised and compared across large numbers of specimens. However, the ability to quantify differences in leaf shape

does not necessarily imply that these differences are sufficiently stable or taxon-specific to support species identification.

This approach is particularly relevant to the genus *Alchemilla*, for which a substantial amount of material is already available in digitised herbarium collections. These collections provide an opportunity to examine leaf-shape variation across numerous specimens, geographical regions, and existing taxonomic identifications. In species of this genus, the leaf is a particularly important morphological feature and has been widely used in morphometric analyses (Sepp and Paal 1998; Pihu et al. 2009; Aghaei 2014). Previous morphometric studies of *Alchemilla* have shown that many microspecies form a morphological continuum (Sepp and Paal 1998). Pihu et al. (2009) investigated the stability of morphological traits and the possibility of distinguishing species, while Zhukova (2020) achieved an approximately 80% correct classification rate for selected groups, although the different microspecies still partially overlapped. The expression of some leaf characters may also vary with environmental conditions, further complicating their taxonomic interpretation (Pihu et al. 2009). Although these studies demonstrated measurable variation in leaf morphology, the presence of statistically detectable differences does not necessarily indicate that leaf shape alone can reliably reproduce species assignments. It therefore remains unclear to what extent outline-based morphometry of digitised herbarium specimens is congruent with existing species identifications and whether it can help position unidentified specimens within the morphological variation represented by labelled material.

Research to date does not provide clear answers to these questions, particularly for large and geographically heterogeneous datasets assembled from digitised herbarium specimens. Therefore, the aims of this study were to: (1) quantify leaf-shape variation among selected European *Alchemilla* taxa using digitised herbarium specimens; (2) determine the extent to which morphometric differentiation was congruent with species identifications recorded on herbarium labels; and (3) assess whether leaf morphometry could support the preliminary evaluation of specimens identified only as *Alchemilla* sp. Rather than treating morphometric similarity as an independent taxonomic identification, we used it to evaluate the position of unidentified specimens within the range of variation represented by the labelled material. More broadly, the study examined the potential and limitations of leaf morphometry as a screening tool for taxonomically complex material in digitised herbarium collections.

Materials and methods

Study material

The study material comprised herbarium specimens assigned to 12 species of the genus *Alchemilla* L.: *A. acutiloba* Opiz, *A. glabra* Neygenf., *A. glaucescens* Wallr., *A. hybrida* (L.) L., *A. mollis* (Buser) Rothm., *A. monticola* Opiz, *A. obtusa* Buser, *A. pastoralis* Buser, *A. plicata* Buser, *A. propinqua* H.Lindb. ex Juz., *A. subcrenata* Buser, and *A. vulgaris* L. The selected taxa belong to a broad complex of morphologically similar European *Alchemilla*, including several microspecies traditionally associated with *A. vulgaris* sensu lato and representatives of morphologically overlapping adjacent groups. The material originated from various lowland and mountainous regions across Europe, including Austria, Belgium, Finland, France, Germany, Italy, Latvia, the Netherlands, Norway, Poland, Slovakia, Slovenia, Sweden, Switzerland, Turkey, and the United Kingdom. Some specimens originated from unknown localities, as the corresponding herbarium labels lacked locality data. The species names were derived from the herbarium labels, and the identity of the plant material was not independently verified in this study. This approach reflected the aim of evaluating the congruence between leaf morphometry and taxonomic information available in digitised herbarium collections rather than conducting a taxonomic revision of the examined material. Moreover, reliable species-level identification in these morphologically complex groups commonly requires combinations of vegetative and reproductive characters that were not consistently visible or preserved on all digitised sheets.

The material comprised 742 leaves selected from 514 herbarium specimens deposited in the following collections: the Meise Botanic Garden (BR), Naturalis Biodiversity Center Amsterdam collection (AMD), Leiden collection (L), Utrecht collection (U) and Wageningen collection (WAG), Royal Botanic Garden Edinburgh (E), Royal Botanic Gardens, Kew (K), University of Gdańsk (UGDA), and the W. Szafer Institute of Botany, Polish Academy of Sciences (KRAM) (Table S1). Herbarium acronyms follow Index Herbariorum (updated continuously). Only fully developed, undamaged, and well-preserved leaves with a clearly discernible and complete blade outline were selected for morphometric analyses. Of the 514 specimens,

491 were assigned on their herbarium labels to one of the 12 species included in the study, whereas 23 specimens, represented by 26 leaves, were identified only as *Alchemilla* sp. These unidentified specimens were included to assess their position within the observed morphometric variation and their similarity to the label-identified material, rather than to infer definitive species assignments. Because all unidentified specimens originated from a single herbarium collection, the conclusions concerning their morphometric affinities were treated as exploratory.

Morphometric analyses

Leaf shape variation was quantified using elliptic Fourier analysis of leaf-blade outlines, expressed as elliptic Fourier descriptors (EFDs), together with four conventional shape indices: aspect ratio, circularity, roundness, and solidity. The combination of outline-based descriptors and conventional indices was used to characterize complementary aspects of leaf shape and to assess the extent of morphological differentiation among the examined *Alchemilla* taxa (Klein and Svoboda 2017).

Digital images of the 742 leaves selected from the 514 herbarium specimens were subjected to image segmentation before contour extraction. The background and elements not belonging to the analysed leaf blade were automatically removed using the BRIA RMBG-2.0 deep neural network model (Zheng et al. 2024). Subsequently, the resulting alpha masks were refined using median filtering, morphological closing, and Gaussian blurring implemented in OpenCV. All operations were performed in Python 3.11.7 (Python Software Foundation 2023) using rembg v. 2.0.84 (Gatis 2026), Pillow v. 12.3.0 (Pillow Team 2026), OpenCV v. 5.0.0 (Bradski 2000), ONNX Runtime v. 1.16.3 (Microsoft Corporation 2023), and NumPy v. 1.26.4 (Harris et al. 2020). The images were further processed in Adobe Photoshop v. 25.0 (Adobe 2023) to correct evident segmentation artefacts and were then saved in BMP format. Image processing was limited to background removal and contour refinement; no deliberate modification of biological structures, including lobes, marginal teeth, or the basal sinus, was performed. Leaf contour analysis was then conducted with the SHAPE software package following the protocol described by Iwata and Ukai (2002).

In the first step, leaf contours were converted into chain codes using the ChainCoder module. The resulting chain codes were subsequently transformed into

normalized elliptic Fourier descriptors (EFDs) using the Chc2Nef module. Twenty harmonics were used to describe each leaf outline, and normalization was performed based on the longest radius, following Klein and Svoboda (2017). Before contour extraction, all leaf images were oriented consistently, with the basal sinus positioned downward and the central apical lobe directed upward. To avoid treating multiple leaves originating from the same herbarium specimen as independent observations, the normalized EFD coefficients were averaged at the specimen level prior to PCA. For specimens represented by more than one leaf, the corresponding coefficients were averaged across the analysed leaves; for specimens represented by a single leaf, the original coefficient values were retained. This procedure resulted in a dataset of 514 independent specimen-level sets of EFD coefficients.

Principal component analysis (PCA) was then performed on the specimen-level EFD coefficients using the PrinComp module and the covariance matrix. The first-harmonic coefficients (a1, b1, c1, and d1) were excluded because they were rendered constant by EFD normalization, while coefficients from the second to the twentieth harmonic (a2-d20; 76 coefficients in total) were included in the analysis. Retained principal components were defined by SHAPE as those for which the proportion of explained variance exceeded 1/NAC, where NAC denotes the number of analysed coefficients. Twelve principal components met this criterion. The specimen-level PCA scores obtained for the 514 herbarium specimens were visualized on a PC1-PC2 score plot (Table S2), generated in R 4.4.3 using the ggplot2 and ggtext packages (R Core Team 2025; Wickham 2016; Wilke and Wiernik 2022). Leaf contours were reconstructed at −2.5 and +2.5 standard deviations from the mean for the first five principal components to facilitate the biological interpretation of the major patterns of shape variation (Fig. 1B).

In parallel, four conventional leaf-shape indices were calculated for each leaf using ImageJ (Abràmoff et al. 2004) and macros prepared according to the protocol of Klein and Svoboda (2017). Aspect ratio, circularity, roundness, and solidity were calculated for individual leaves and subsequently averaged at the herbarium specimen level. For specimens represented by a single leaf, the original values were retained. Relationships among the specimen-level mean values of the analysed shape indices and scores of the first two principal components derived from the EFD analysis were assessed using a Pearson correlation matrix generated in R 4.4.3 (R Core Team 2025)

within RStudio v. 2024.04.1 “Chocolate Cosmos” (Posit Team 2024), with the corrplot package v. 0.95 (Wei and Simko 2024) (Fig 2).

To assess whether the selected species formed distinct clusters, PERMANOVA, pairwise PERMANOVA, an assessment of multivariate homogeneity of group dispersions (PERMDISP), and non-metric multidimensional scaling (NMDS) were performed. To reduce redundancy, only weakly correlated variables selected on the basis of the preceding correlation analysis were included. Specimens identified only as *Alchemilla* sp. were excluded from species-level comparisons. Five species represented by fewer than 10 specimens: *A. acutiloba* (n = 2), *A. hybrida* (n = 1), *A. obtusa* (n = 1), *A. pastoralis* (n = 7), and *A. vulgaris* (n = 4) were also excluded. Consequently, the PERMANOVA dataset comprised 476 specimens assigned to seven species: *A. glabra*, *A. glaucescens*, *A. mollis*, *A. monticola*, *A. plicata*, *A. propinqua*, and *A. subcrenata*. The analyses were conducted in R 4.4.3 (R Core Team 2025) using RStudio 2024.04.1 “Chocolate Cosmos” (Posit Team, 2024), with the vegan v. 2.7-5 (Oksanen et al. 2026) and cluster v. 2.1.8.2 (Maechler et al. 2026) packages. Data visualization was performed using ggplot2 v. 4.0.3 (Wickham 2016) and ggrepel v. 0.9.8 (Slowikowski 2026). Figures were edited and assembled using Inkscape v. 1.3 (Inkscape Project 2023).

To explore the overall structure of leaf-shape variation independently of the existing taxonomic identifications, NMDS (using Euclidean distances calculated from the standardized, non-redundant morphometric variables) and hierarchical cluster analysis were performed using the complete dataset of 514 herbarium specimens. Hierarchical clustering using the Ward.D2 method was conducted on the same standardized dataset and distance matrix. The optimal number of clusters was evaluated using mean silhouette widths calculated for solutions ranging from k = 2 to k = 9. Based on this criterion, two phenotypic clusters were retained. These groups were subsequently indicated on the NMDS ordination to visualize their distribution in multivariate morphometric space.

Results

The complete morphometric dataset comprised 742 leaves representing 514 herbarium specimens. Of these, 491 specimens were assigned on their herbarium labels to 12 identified species: *Alchemilla acutiloba* (n = 2), *A. glabra* (n = 238), *A. glaucescens* (n = 52), *A. hybrida* (n = 1), *A. mollis* (n = 20), *A. monticola* (n = 101), *A. obtusa* (n = 1), *A. pastoralis* (n = 7), *A. plicata* (n = 27), *A. propinqua* (n = 16), *A. subcrenata* (n = 22), and *A. vulgaris* (n = 4). The remaining 23 specimens, represented by 26 leaves, were identified only as *Alchemilla* sp. (Table S2). All 514 specimens were included in the PCA, NMDS, and hierarchical clustering. By contrast, species-level PERMANOVA and PERMDISP were restricted to 476 specimens representing the seven species with at least 10 available specimens (Table S2).

The PCA of the specimen-level mean normalized EFD coefficients showed considerable overlap among the examined *Alchemilla* taxa in the PC1-PC2 ordination space, with no clear species-specific separation (Fig. 1A). PC1 accounted for 39.11% of the total variation and PC2 for 14.82%, together explaining 53.93%. The subsequent components explained smaller proportions of variation: PC3, 7.00%; PC4, 5.44%; and PC5, 4.69%. Together, the first five components accounted for 71.06% of the total variation in leaf outline. Reconstruction of leaf contours at ±2 SD showed that these components reflected continuous variation in overall blade proportions, the depth and shape of the basal sinus, and the configuration of the blade margin (Fig. 1B). Changes between the reconstructed extreme contours were gradual and did not indicate the presence of sharply delimited leaf-shape categories (Fig. 1; Table S2).

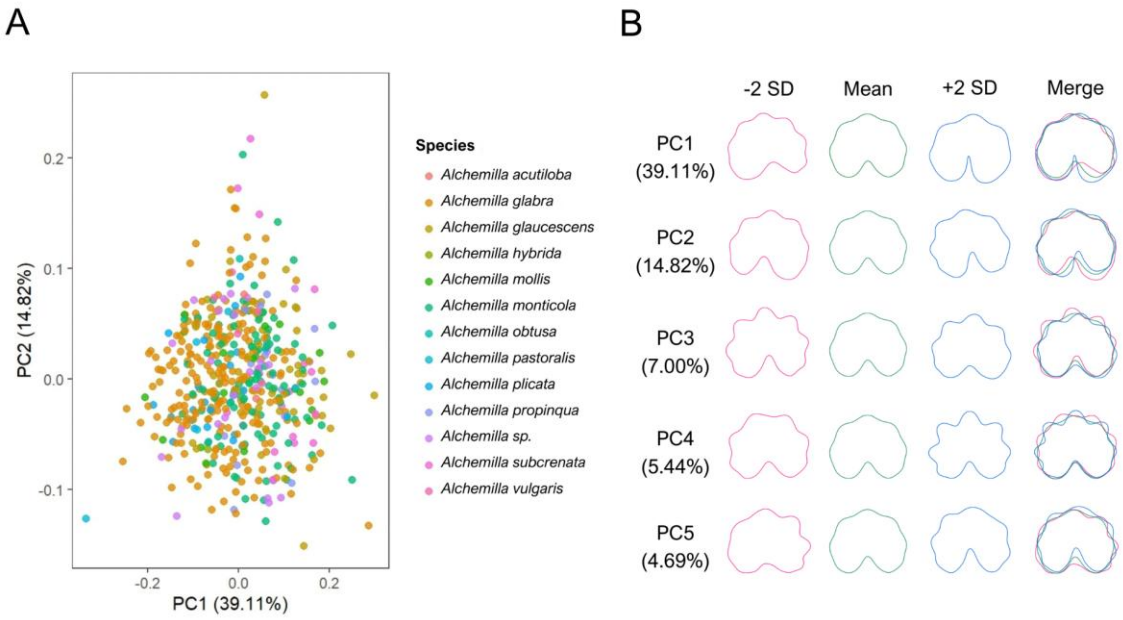


Figure 1. Principal component analysis (PCA) of leaf-outline variation based on normalized elliptic Fourier descriptors (EFDs) in the examined *Alchemilla* taxa. A. Distribution of 514 herbarium specimens along PC1 and PC2, based on specimen-level mean EFD coefficients. B. Reconstructed leaf outlines at -2 SD, the mean, and +2 SD for PC1-PC5. Merged outlines show relative shape variation along each component.

Relationships among aspect ratio, circularity, roundness, solidity, and the first two principal component scores (PC1 and PC2) derived from the analysis of EFDs were assessed using a Pearson correlation matrix based on specimen-level mean values for the 514 herbarium specimens. The strongest relationship was a negative correlation between aspect ratio and roundness ($r = -0.94$; Fig. 2), indicating that these two indices contained largely redundant information.

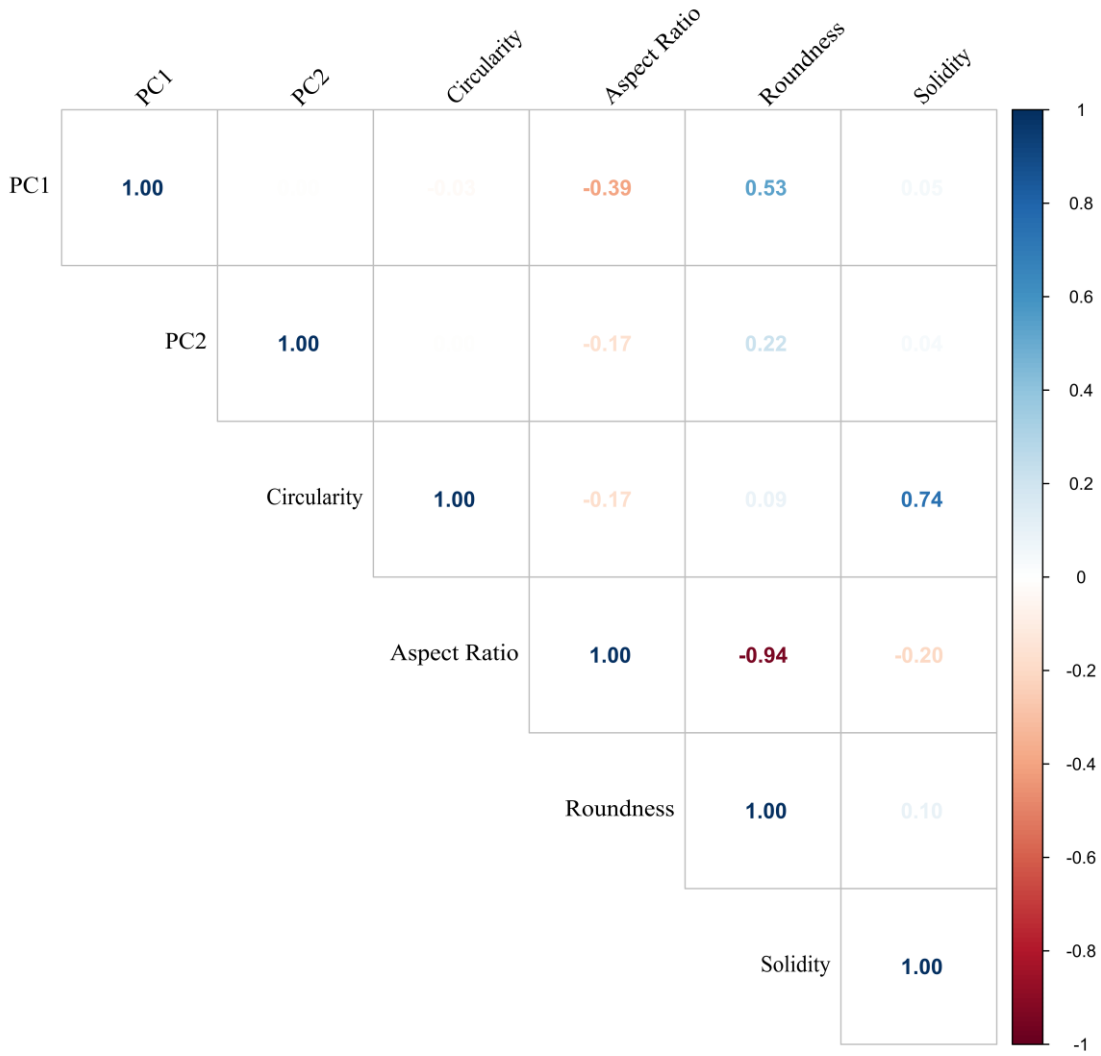


Figure 2. Pearson correlation matrix showing relationships between the first two principal component scores derived from the analysis of elliptic Fourier descriptors (PC1 and PC2) and the analysed leaf-shape indices, based on specimen-level mean values (n = 514).

The global PERMANOVA revealed significant differences in multivariate leaf morphology among the analysed groups ($F_{6,469}$ = 5.627, R^2 = 0.067, p = 0.0001; 9999 permutations; Euclidean distance). Group identity explained approximately 6.7% of the total variation in leaf morphology. PERMDISP revealed no significant differences in multivariate dispersion among groups ($F_{6,469}$ = 1.705, p = 0.1179; 9999 permutations), indicating that within-group dispersions were homogeneous. Thus, the significant global PERMANOVA result was unlikely to have been driven primarily by differences in multivariate dispersion among species.

Pairwise PERMANOVA comparisons revealed significant differences in 12 of the 21 pairwise comparisons. The largest differences were observed between *A. plicata* and *A. propinqua* (R^2 = 0.2060, adjusted p = 0.0007) and between *A. plicata* and *A. subcrenata* (R^2 = 0.1642, adjusted p = 0.0007) (Table 1).

Table 1. Significant pairwise differences among the analysed *Alchemilla* species based on pairwise PERMANOVA. Only significant comparisons are shown. Values are rounded to four decimal places. All results, including non-significant comparisons, are provided in the Supplementary Material (Table S3).

No.	Group 1	Group 2	F	R^2	p	p adj
1	*A. monticola*	*A. plicata*	11.9553	0.0867	0.0001	0.0007
2	*A. plicata*	*A. propinqua*	10.6346	0.2060	0.0001	0.0007
3	*A. plicata*	*A. subcrenata*	9.2306	0.1642	0.0001	0.0007
4	*A. glabra*	*A. monticola*	9.8019	0.0283	0.0002	0.0008
5	*A. glabra*	*A. propinqua*	12.9408	0.0488	0.0002	0.0008
6	*A. mollis*	*A. plicata*	7.4204	0.1416	0.0004	0.0014
7	*A. monticola*	*A. propinqua*	7.1183	0.0583	0.0014	0.0042
8	*A. glabra*	*A. glaucescens*	5.1781	0.0177	0.0056	0.0147
9	*A. glabra*	*A. plicata*	5.3632	0.0200	0.0070	0.0163
10	*A. glabra*	*A. subcrenata*	4.5503	0.0173	0.0110	0.0231
11	*A. glabra*	*A. mollis*	4.1624	0.0160	0.0145	0.0277
12	*A. propinqua*	*A. subcrenata*	3.9961	0.0999	0.0279	0.0488

The NMDS ordination based on Euclidean distances provided an acceptable, although imperfect, two-dimensional representation of the multivariate morphological variation (stress = 0.1544). Considerable overlap among taxa was observed, and no species formed a clearly isolated group in the ordination space (Fig. 3). Although differences in the relative positions of some specimens were visible, the distributions of the taxonomic groups overlapped extensively, indicating that the major patterns of leaf-shape variation did not correspond to clearly separated species-level groups (Table S4).

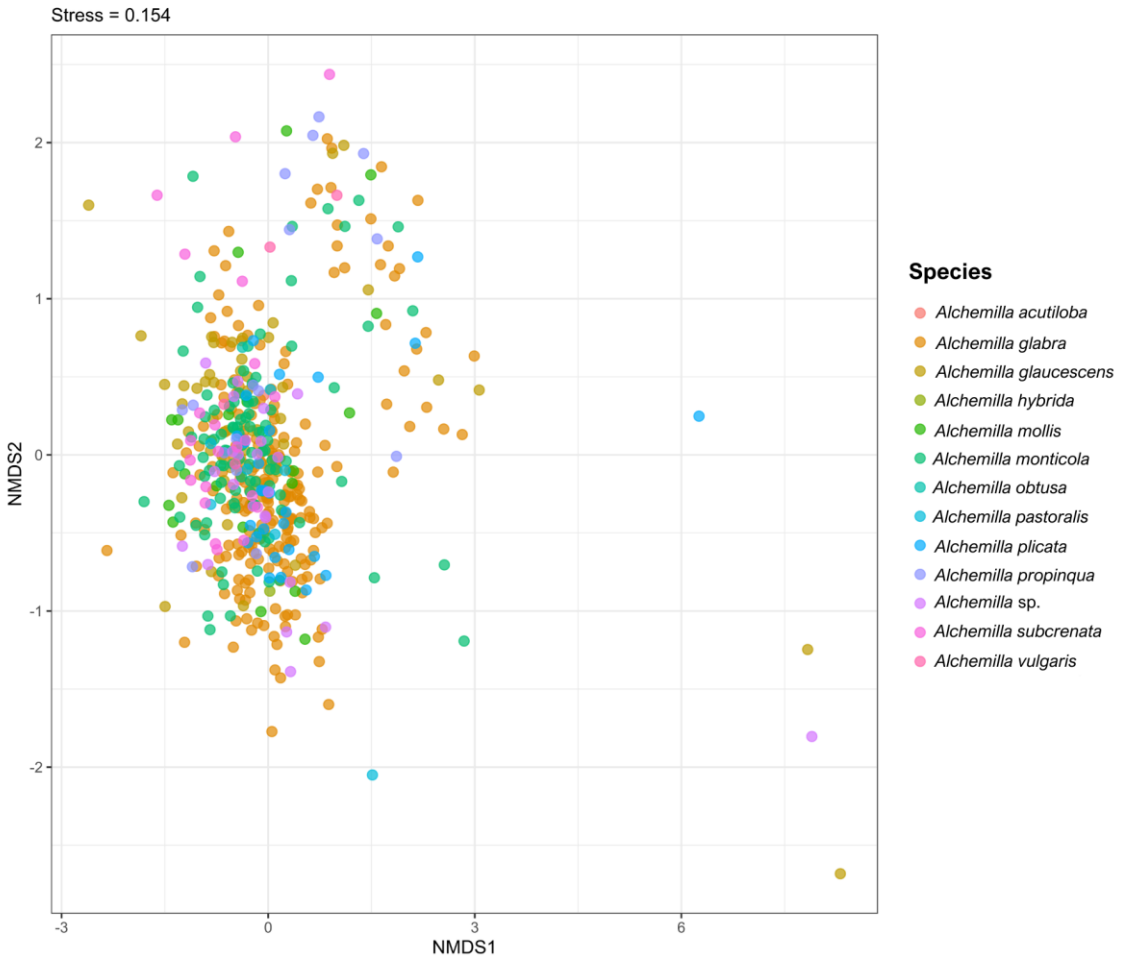


Figure 3. Non-metric multidimensional scaling (NMDS) ordination of the analysed *Alchemilla* specimens based on standardised leaf-shape variables and Euclidean distances. Each point represents an individual herbarium specimen, and colours indicate the identification provided on the herbarium label. Stress = 0.1544. All NMDS scores are provided in the Supplementary Material (Table S4).

To investigate whether distinct phenotypic groups could nevertheless be identified, hierarchical clustering using the Ward.D2 method was performed for all 514 herbarium specimens. Silhouette analysis indicated that the optimal number of clusters was two, as indicated by the highest silhouette value (0.49; Fig. 4). Cluster 1 comprised 446 specimens (86.8%), whereas Cluster 2 comprised 68 specimens (13.2%). The resulting clusters were visualized in a circular dendrogram (Fig. 5), and cluster membership was subsequently superimposed on the NMDS ordination of the complete dataset (Fig. 6). Cluster 1 formed a relatively compact group, whereas Cluster 2 was more broadly dispersed, suggesting greater internal morphological variation. Although the clusters

occupied partly distinct regions of the ordination space, they were not completely separated in the two-dimensional NMDS representation.

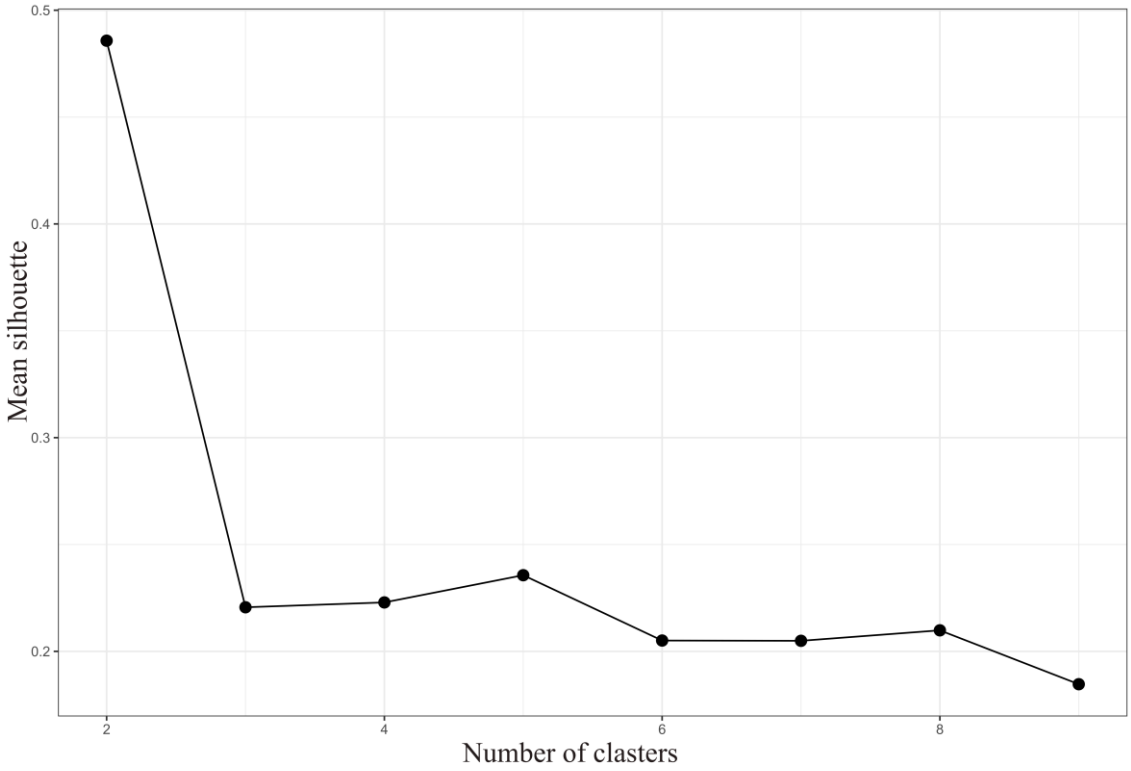


Figure 4. Mean silhouette width for different numbers of clusters (k = 2-9) used to evaluate the clustering structure of the analysed specimen-level leaf-morphometric dataset.

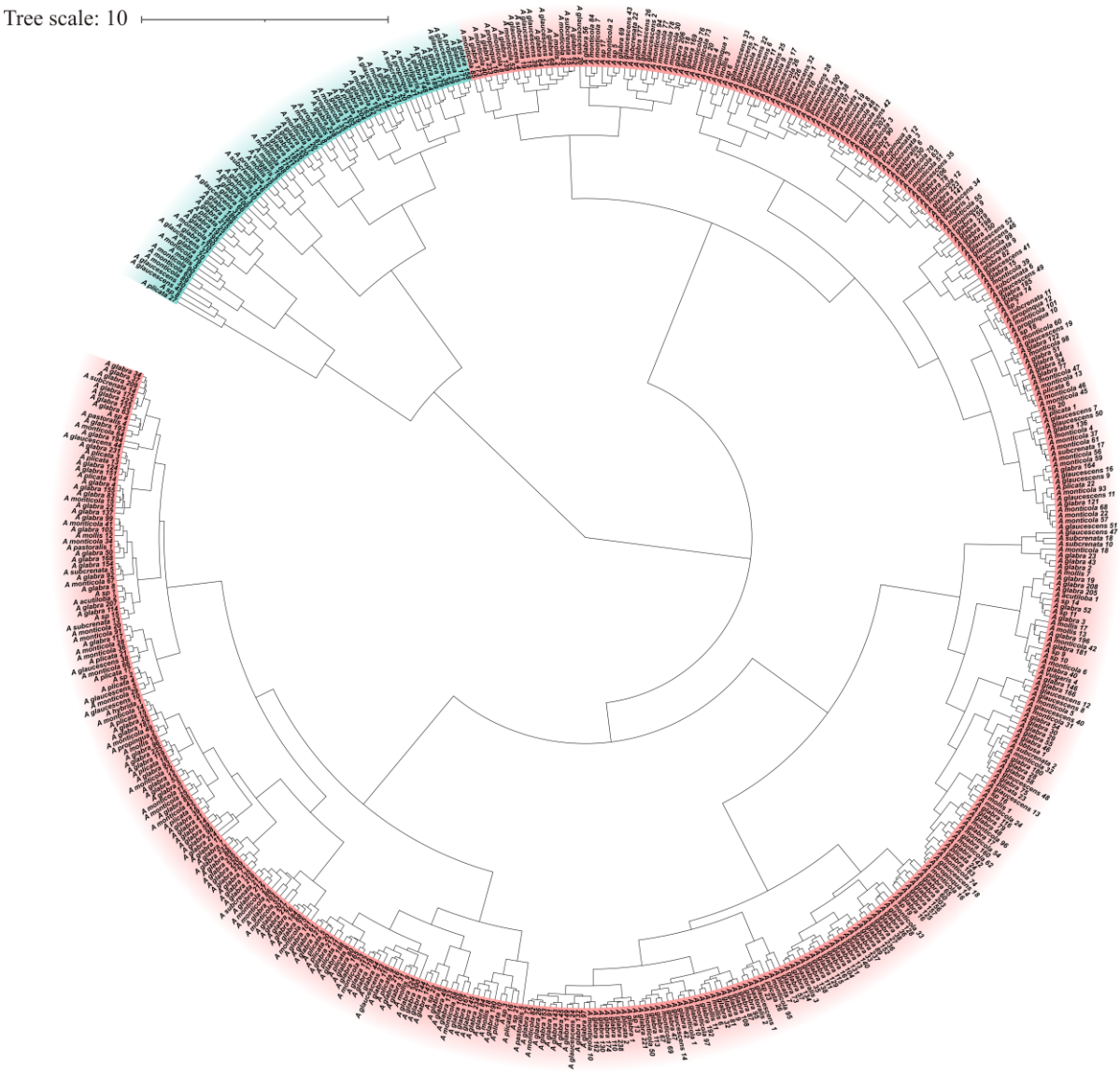


Figure 5. Circular dendrogram of the 514 analysed herbarium specimens based on hierarchical clustering using Ward's method (Ward.D2). The two main phenotypic clusters identified from the dendrogram and silhouette analysis are indicated by different colours.

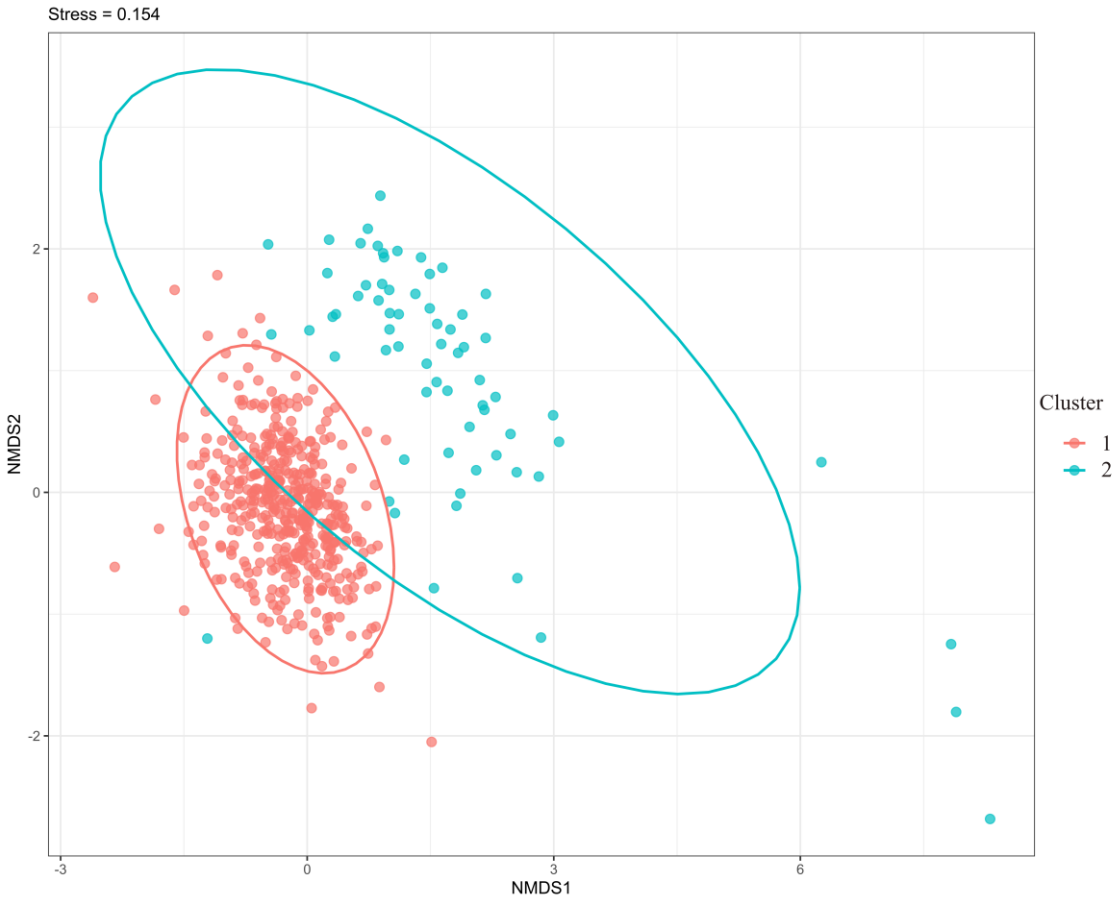


Figure 6. Non-metric multidimensional scaling (NMDS) ordination of the 514 analysed herbarium specimens, showing the two phenotypic clusters identified by hierarchical clustering using Ward's method (Ward.D2). Ellipses indicate the distribution of the two clusters in the ordination space. Stress = 0.1544.

The taxonomic composition of the two clusters showed that neither phenotypic group corresponded to a single taxon (Fig. 7). Each cluster comprised herbarium specimens assigned on their labels to several *Alchemilla* taxa, and most taxa were represented in both clusters. No taxon was restricted exclusively to Cluster 2, whereas the few taxa recorded only in Cluster 1 were represented by very small sample sizes (*A. acutiloba*, *A. hybrida*, *A. obtusa*, *A. pastoralis*). Thus, the phenotypic groups identified by hierarchical clustering showed only limited correspondence with taxonomic identity, indicating substantial overlap in leaf morphology among the studied taxa (Table S5).

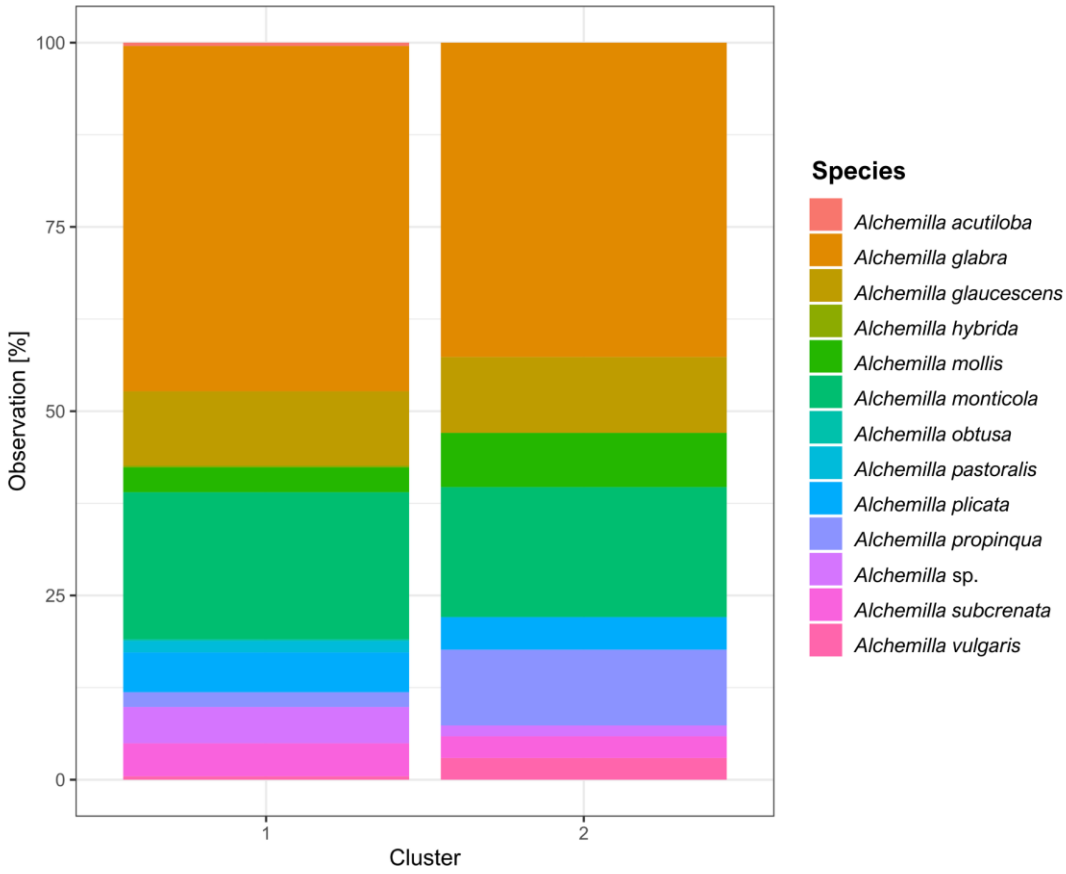


Figure 7. Relative distribution of the analysed *Alchemilla* taxa and unidentified *Alchemilla* sp. specimens between the two phenotypic clusters identified by hierarchical clustering. Percentages were calculated separately within each taxon based on specimen-level cluster assignments (Table S5).

Among taxa represented by at least 10 specimens, *A. propinqua* had the largest proportion of specimens assigned to Cluster 2 (7 of 16 specimens; 43.8%), followed by *A. mollis* (5 of 20; 25.0%). In the remaining adequately sampled species, the proportion assigned to Cluster 2 ranged from 9.1% in *A. subcrenata* to 13.5% in *A. glaucescens*. The four specimens of *A. vulgaris* were divided equally between the two clusters, but this result should be interpreted cautiously because of the small sample size. Among the specimens identified only as *Alchemilla* sp., 22 of 23 (95.7%) were assigned to Cluster 1, whereas one specimen (4.3%) was assigned to Cluster 2 (Fig. 7; Table S5).

Although 22 of the 23 unidentified specimens were assigned to Cluster 1, this cluster also contained specimens assigned on their herbarium labels to all 12 named species included in the study. Consequently, membership in Cluster 1 did not provide a basis for assigning the unidentified specimens to any particular species. More generally, neither phenotypic cluster corresponded to a single taxon, and the clustering analysis therefore did not support species-level identification of the *Alchemilla* sp. specimens based on the analysed leaf-shape characters alone (Figs 6, 7; Table S5).

Discussion

PCA based on specimen-level mean normalized EFD coefficients showed that leaf-outline variation was continuous and distributed across several principal components. Although PC1 and PC2 together accounted for 53.93% of the total variation, considerable overlap among the examined taxa in the PC1-PC2 space indicated limited species-level separation based on leaf outline alone. The gradual changes visible in the reconstructed contours further suggest that the analysed specimens formed a morphological continuum rather than discrete, species-specific leaf-shape categories. This pattern is consistent with previous studies on the genus *Alchemilla*. Many species exhibit a high degree of morphological similarity, making their unambiguous separation considerably more difficult (Sepp and Paal 1998; Pihu et al. 2009). Furthermore, previous morphometric analyses of selected *Alchemilla* species demonstrated overlapping ranges of leaf-shape variation (Zhukova 2020). The results obtained in the present study therefore highlight the limitations of using leaf outline alone as an independent diagnostic character at the species level, at least for the examined set of closely related taxa and herbarium material.

The conventional shape indices complemented the outline-based EFD analysis by describing selected geometric properties of the leaf blade. Relationships among most of the analysed indices and the first two EFD-derived principal component scores were weak to moderate. A very strong negative correlation between aspect ratio and roundness ($r = -0.94$) indicated that these two variables largely describe the same underlying aspect of leaf geometry, and roundness was therefore excluded from subsequent multivariate analyses. Previous studies on *Alchemilla* have similarly shown that the diagnostic value of individual morphological characters may be limited or uneven, whereas combinations of multiple characters may provide more useful information for species differentiation (Sepp and Paal 1998; Sepp et al. 2000; Pihu et al. 2009). Nevertheless, even the multidimensional analyses applied in the present study did not result in clear species-level separation. Thus, combining several leaf-shape variables improved the quantitative description of morphological variation but did not provide an unambiguous basis for species identification.

The global PERMANOVA detected significant differences in multivariate leaf morphology among the seven adequately sampled species, but species identity explained only 6.7% of the total variation. Pairwise tests further showed that the degree of differentiation was uneven: 12 of the 21 comparisons remained significant after correction for multiple testing, whereas the remaining comparisons did not. Moreover, several statistically significant comparisons were characterized by low R^2 values, indicating relatively small differences between group centroids. The non-significant PERMDISP result indicated no evidence of substantial differences in within-group multivariate dispersion, suggesting that the observed PERMANOVA pattern was not primarily driven by unequal dispersion among groups. The NMDS ordination nevertheless revealed considerable overlap among taxa, with none of the species forming a clearly isolated group. Similar patterns have been reported in previous multivariate studies of *Alchemilla*, in which statistically distinguishable taxa or morphometric groups nevertheless showed substantial overlap or intermediate specimens (Sepp and Paal 1998; Sepp et al. 2000; Zhukova 2020). Pihu et al. (2009) likewise demonstrated close morphological similarity between some apomictic microspecies. Thus, although statistically significant morphometric differences occurred between selected taxa, they were insufficient to define clear species-level groups or provide reliable diagnostic boundaries based on the analysed leaf characters.

Hierarchical clustering provided a similar result. Two main phenotypic clusters were distinguished, but neither corresponded to a single label-defined taxon. Both clusters contained specimens assigned to several *Alchemilla* taxa, indicating that the clustering pattern primarily reflected similarities in the analysed set of morphometric characters rather than taxonomic boundaries. Most specimens belonged to Cluster 1 (446 specimens; 86.8%), whereas Cluster 2 contained only 68 specimens (13.2%) and showed greater dispersion in the NMDS ordination. Similar difficulties in recovering clear species-level groups from multivariate morphological data have previously been reported in *Alchemilla*, where cluster-based analyses revealed substantial morphological continuity among microspecies (Sepp and Paal 1998; Sepp et al. 2000). Since most of the species examined in the present study were represented in both clusters, this result further supports the conclusion that similar leaf shapes may occur in different label-identified species and that leaf morphometry alone does not reproduce their taxonomic boundaries. Cluster 2 may represent a less frequent region of the continuous

leaf-shape variation present in the dataset. Its composition could reflect biological sources of variation, including environmental or developmental effects, but may also have been influenced by preservation-related deformation, image-processing uncertainty, or incorrect herbarium-label identifications. These alternatives cannot be distinguished using the present data, and the two clusters should therefore be interpreted as descriptive phenotypic groups rather than taxonomically discrete entities.

One of the objectives of the study was to assess whether specimens identified only as *Alchemilla* sp. could be assigned more precisely using the applied morphometric approach. Most unidentified specimens (22 of 23) were assigned to Cluster 1; however, this cluster also contained specimens assigned on their herbarium labels to all 12 named species included in the study. Therefore, the clustering pattern did not provide sufficient evidence to assign the unidentified specimens to any particular species. Moreover, specimens identified as *Alchemilla* sp. cannot be assumed to represent a homogeneous taxonomic group, and comparisons treating them collectively as a single species-level group should be interpreted with caution. This limitation is compounded by the fact that all unidentified specimens originated from the UGDA collection; consequently, patterns observed for this group cannot be readily generalized to unidentified *Alchemilla* material from other collections. Their concentration in one collection also prevents taxonomic status from being fully separated from possible collection-related effects. This is particularly important when working with herbarium collections, in which taxonomic misidentifications may occur and subsequently influence downstream analyses (Goodwin et al. 2015). A more reliable assessment would require individual comparison of unidentified specimens with well-documented and taxonomically verified reference material (Arno et al. 2026), preferably combined with examination of additional diagnostic characters and, where possible, molecular evidence. The present results therefore demonstrate morphometric similarity within the analysed character space but do not support unambiguous species-level identification.

The selection of well-preserved and apparently undamaged leaves reduced the influence of obvious specimen defects but could not eliminate possible changes in leaf shape caused by pressing, drying, mounting, long-term storage, or image processing. Consequently, preservation-related effects cannot be completely excluded as a source of morphometric variation. The observed variability may also reflect environmental and developmental factors, which are known to influence leaf size and shape

(Fritz et al. 2018). Environmental effects on morphological characters have also been investigated in *Alchemilla*, although their influence was found to be relatively limited in the microspecies examined by Pihu et al. (2009). Such variation may nevertheless partly contribute to some of the patterns observed in the present analyses, including the composition of Cluster 2. However, environmental and geographic effects could not be directly evaluated because precise locality, habitat, and environmental data were unavailable for some specimens, particularly those from older herbarium collections. Such limitations are common in herbarium-based trait studies, where geographic precision and detailed environmental metadata may be incomplete or inconsistent (Heberling 2022). Consequently, it was not possible to assess whether conditions occurring during the growing season influenced leaf-blade development and the values of the analysed morphometric traits. Potential collection-related effects should also be considered because differences in specimen preparation, mounting, imaging, or taxonomic composition among herbaria could contribute to the observed pattern. Future studies should therefore include larger and more geographically representative samples with well-documented provenance and environmental data, taxonomically verified reference specimens, and explicit assessment of collection effects.

At the same time, the set of characters used in the present study focused mainly on overall leaf-blade shape, selected morphometric indices, and the first two principal components derived from EFDs. It is therefore possible that additional leaf characters could reveal patterns of differentiation that were not captured by the variables retained in the present multivariate analyses. Future studies could incorporate targeted measurements of lobe and tooth geometry, basal-sinus depth and width, and quantitative traits related to venation, including vein length, vein angles, and proportions between particular leaf structures. Landmark-based analyses focused on selected structural regions of the leaf may also provide complementary information. Although some of these features are partly represented in EFD-based outlines, targeted measurements or landmarks may characterize localized differences that are not readily isolated by analyses of the complete contour. Previous studies have demonstrated that leaf venation and architecture can provide substantial discriminatory information for taxonomic identification. In *Camellia*, the combination of morphological and venation characters enabled highly accurate classification of a large number of species (Lu et al. 2012), while venation-based landmarks were successfully used to distinguish

closely related *Quercus* species and their natural hybrids (Botticelli et al. 2025). More recently, landmark-based analyses incorporating vein junctions in *Rubus crataegifolius* showed higher discriminatory power than EFD-based outline analysis alone, indicating that venation architecture may capture taxonomically informative variation not represented by leaf outline (Kim et al. 2026). These findings suggest that integrating detailed structural and venation characters with outline-based morphometry may increase the diagnostic value of leaf morphology in *Alchemilla*. Nevertheless, even an expanded leaf-based approach should be treated as complementary to conventional taxonomic assessment incorporating other vegetative and reproductive characters, rather than as a standalone method of species identification.

Conclusions

Despite the observed variation in leaf outline, PCA based on specimen-level mean EFD coefficients revealed considerable overlap among the studied taxa, indicating that leaf outline alone does not provide clear species-level separation. Although PERMANOVA detected significant differences among the adequately sampled species, taxonomic identity explained only a small proportion of the total morphometric variation, and extensive overlap remained in the NMDS ordination. Similarly, the two phenotypic clusters reflected broad patterns of leaf-shape similarity but did not correspond to the species identifications provided on the herbarium labels.

The morphometric analyses did not allow specimens identified as *Alchemilla* sp. to be assigned unambiguously to any of the examined species. Although 22 of the 23 unidentified specimens were assigned to Cluster 1, this cluster also contained specimens bearing the names of all 12 examined species. Cluster membership therefore indicated broad morphometric similarity but did not provide sufficient evidence for species-level identification. Because all unidentified specimens originated from a single herbarium collection, conclusions concerning this material should be regarded as exploratory and should not be generalized to unidentified *Alchemilla* specimens from other collections.

Overall, digital leaf morphometry provides a reproducible means of quantifying phenotypic variation and identifying specimens or groups that warrant further taxonomic examination. However, its standalone diagnostic value was limited for the closely related *Alchemilla* taxa examined here, and it cannot replace identification based on a broader combination of vegetative and reproductive characters. Future studies should combine outline-based morphometry with targeted analyses of leaf architecture

and venation, taxonomically verified reference material, more balanced sampling, and explicit assessment of environmental, preservation-related, and collection-specific effects.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical approval was required for this study.

Artificial Intelligence (AI) use

The authors accept full responsibility for the content of the manuscript, including the disclosure of any use of AI. No AI tools were used in the preparation of this manuscript.

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Author contributions

Conceptualization: AMKC, JJ. Investigation: AMKC, JJ. Resources: AMKC. Writing -original draft: AMKC, SN, JJ. Writing - review and editing: AMKC, SN, JJ, DLSZ. Supervision: SN, DLSZ.

All authors agree to be responsible for the accuracy and consistency of the work.

Author ORCIDs

A.M. Kosiróg-Ceynowa https://orcid.org/0000-0001-6042-8218

S. Nowak https://orcid.org/0000-0002-0496-1023

J. Jaskólska https://orcid.org/0000-0003-2002-1231

D. L. Szlachetko https://orcid.org/0000-0002-3210-7537

Data availability

The data supporting the findings of this study are available in the main text and Supplementary Materials.

Suplementy do pracy nr 3

Supplementary Table S1. Herbarium material used in the morphometric study of *Alchemilla.*

Supplementary Table S1. Herbarium material used in the morphometric study of *Alchemilla* .

Specimen number	Species	Herbarium	Locality
WAG.1561156	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Baarn.
WAG.1503755	*Alchemilla mollis* (Buser) Rothm.	Naturalis Biodiversity Center	Unknown
WAG.1503792	*Alchemilla propinqua* H.Lindb. ex Juz.	Naturalis Biodiversity Center	Europe; Finland; Ostrobottnia kajanensis: Kajaani, Polvila, meadow. [?].
WAG.1503754	*Alchemilla mollis* (Buser) Rothm.	Naturalis Biodiversity Center	Unknown
WAG.1503812	*Alchemilla subcrenata* Buser.	Naturalis Biodiversity Center	Europe; Latvia; Vidzeme Province, Madona district: Vestiena.
L.1888231	*Alchemilla subcrenata* Buser.	Naturalis Biodiversity Center	Europe; Norway; Hvalstad near Asker.
L.1889332	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Sweden; Swedish flora, Södermanland Province, Torö parish, Bråten, in a meadow.
L.1889323	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; United Kingdom; Scotland, in natural pasture, Patterson near Ojlascow.
L.1889090	*Alchemilla plicata* Buser.	Naturalis Biodiversity Center	Unknown; Eastern Fennoscandia, southern Tavastia, Padasjoki parish, Vesijako, Peltointausta, in a meadow.
L.1889097	*Alchemilla plicata* Buser.	Naturalis Biodiversity Center	Unknown; Savoy flora: in pastures on Mt Salève near Geneva.
L.1889318	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; United Kingdom; Flora of the British Isles, Durham: Jeesdale, Langsdale Beck, few plants at edge of stream.
L.1888237	*Alchemilla subcrenata* Buser.	Naturalis Biodiversity Center	Europe; Sweden; Uppland Province, Stockholm, Freskati, grassy place.
L.1889317	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Norway; Espelandsdalen, Granvik, roadside verge.
L.1889096	*Alchemilla plicata* Buser.	Naturalis Biodiversity Center	Europe; Finland; Finnish flora, Kl. Sortavala, Buorlahti, in a grassy meadow.
L.1889095	*Alchemilla plicata* Buser.	Naturalis Biodiversity Center	Europe; Sweden; Swedish flora, Södermanland Province, Strängnäs parish, Sundby, in a meadow.
L.1889326	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Sweden; near Tännaby in Norrbotten.
L.1888234	*Alchemilla subcrenata* Buser.	Naturalis Biodiversity Center	Unknown; Silesian flora. Riesengebirge: slopes by the Kleiner Teich.
L.1889320	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; United Kingdom; Scotland, Alasgow, Whitecraigs, ruderal site.
L.1889093	*Alchemilla plicata* Buser	Naturalis Biodiversity Center	Unknown; Riga, Latvia, Lessland, Cesis district, Priexuli, ditch margin.
L.1888235	*Alchemilla subcrenata* Buser	Naturalis Biodiversity Center	Unknown; Silesian flora: Riesengebirge; Kleiner Teich.
L.1888240	*Alchemilla subcrenata* Buser	Naturalis Biodiversity Center	Unknown; Leningrad Province, Priozersk district, northern shore of Lake Otradnoje, at the edge of mixed forest.
L.1889102	*Alchemilla propinqua* H.Lindb. ex Juz.	Naturalis Biodiversity Center	Europe; Sweden; Swedish flora, Värmland Province, Norra Råda parish, Östra Råda, grassy place beside the road to the parsonage.
L.3260878	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; near Wassenaar, ditch bank along a side road off the Wassenaar–Katwijk road.
L.3260066	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Warnsveld.
L.3260145	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Friesland Province, Barradeel municipality, SW of Minnertsga village, verge of a country road, IVON: 5.46.
L.3260194	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; roadside toward Jorwerd, side road off the Weidum–Bozum road.
L.3260013	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Friesland; ; Bergum
L.3249939	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; just before the (last) of Grintus, dike near Haren.
L.3260105	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Baarle Nassau, on the steep bank of the Merkske, 50.44.42.
L.3260021	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Lunteren, Postweg.
L.3249853	*Alchemilla mollis* (Buser) Rothm.	Naturalis Biodiversity Center	Europe; Netherlands; Zuid-Beveland, roadside verge south of Ovezande.
L.3260170	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; along the Winschoterdiep, just outside Groningen, on the front side of the gravel road.
L.3260053	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; at the end, J6.14.44.
L.3260177	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Bissen, Z.L.
L.3260161	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Breda, in an arable field.
L.3260094	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	near Weerselo, between the lock at Rentum and Nijenkampsweg, at the upper edge of the bank vegetation, 28.38.21.
L.3260204	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Reest near Meppel, riverside land.
L.3249961	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Vichnaal bij!
L.3260030	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Unknown
L.3249894	*Alchemilla subcrenata* Buser	Naturalis Biodiversity Center	Europe; Netherlands; Rolderdiep, south of Gasteren, grassland, km grid square: 12.35.51.
L.3260168	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; on a ditch bank at Denekamp, M8 31 21.
L.3260027	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; floodplain of the Vecht near Van Agnietenberg.
L.3260104	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Oostermeer.
L.3260069	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; near Arnhem, under scrub.

L.3249992	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Loofschans. ?
L.3260067	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Unknown
L.3260076	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Groningen Province, Eenrum, roadside at Pieterburen.
L.3260071	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Beek (Villapark) P6 63 14.
L.3249952	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Marquette, lawn.
L.3260127	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Bunde-Kalverberg.
L.3249960	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Reenwijk, Groene Ree, Z.H.
L.3260169	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; on the ramparts of Groningen (near the Aapoort).
L.3249895	*Alchemilla subcrenata* Buser	Naturalis Biodiversity Center	Europe; Netherlands; Rolderdiep, south of Gasteren (Dr.), meadow.
L.3249923	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; batteries at Blaauw Kapel, near Utrecht.
L.3260072	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Groesbeek, Q6 23 22.
L.3260009	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; along the Tongelroyse Beek near Kastert, near Weert.
L.3260151	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Hei- en Boeicop, canal verge (Merwede Canal) near de Huibert, grid square 38.37.22.
L.3249956	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Rotterdam.
L.3249980	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Liesbosch.
L.3249889	*Alchemilla subcrenata* Buser	Naturalis Biodiversity Center	Unknown
L.3260149	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	municipality, Groningen, low on a ditch bank, on the N side, IVON grid square 3.45.54.
L.3260016	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Groningen; ; Veendam
L.3260196	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Ooster-begraafplaats te Amsterdam.
L.3260209	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; road between Eelde and Haren.
L.3260119	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Twizel, grid square H6-45-33, verge of Gron Straatweg.
L.3260188	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Baarn, Groeneveld.
L.3260159	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Groesbeek.
L.3260125	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; forest edge on the boundary of Onderste Bos and Bovenste Bos; Epen (L.).
L.3249986	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Unknown
L.3260122	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; near Bergumermeer.
L.3249959	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; on the rough lane [?] near Wassenaar.
L.3260008	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Unknown
L.3260150	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Gem. Maarssen, Doornburgh.
L.3260186	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Meppel, along the road to Haphorst.
L.3260157	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Utrecht (bank of Catharijnesingel).
L.3260062	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; near Zwolle, on the towpath toward Almelo.
L.3260190	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Denekamp, meadow near Harsseveldbrug, south of the Almelo–Denekamp Canal.
L.3249997	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Basel, Rakens hamlet, near the small bridge over the Chaamsche Beek.
L.3249862	*Alchemilla mollis* (Buser) Rothm.	Naturalis Biodiversity Center	Europe; Netherlands; Haldeurn, roadside.
L.3260101	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Reest near Meppel, L6.16.'42.
L.3260088	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Kootstertille, Kwartierhok: H6-55-14/22.
L.3249973	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Unknown
L.3249857	*Alchemilla mollis* (Buser) Rothm.	Naturalis Biodiversity Center	Europe; Netherlands; Nijmegen-Kappitel weg.
L.3260022	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Maartensdijk near Utrecht.
L.3249888	*Alchemilla subcrenata* Buser	Naturalis Biodiversity Center	Europe; Netherlands; Drentsche A near Anderen, ditch edge near the mouth (to the N) of the Scheebroeker stream.
L.3260173	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; along the Winschoterdiep near Groningen, in meadows.
U.1541786	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Unknown; Kampen kortes gym.
U.1541617	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Austria; Vorarlberg, Bregenzerwald: between Sulzberg and Lindengschwend, wet meadow with Eriophorum.
U.1542452	*Alchemilla subcrenata* Buser	Naturalis Biodiversity Center	Haimbachalm–Rettenbachalm near Sölden, dwarf-shrub heath; silicate.
U.1542453	*Alchemilla subcrenata* Buser	Naturalis Biodiversity Center	Europe; Austria; North Tyrol, Upper Inn Valley: left Inn floodplain between Landeck and Urgen.
U.1541616	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Alpe Malasch and Alpe Mason near Braz, partly on limestone under Pinus mugo.
U.1541618	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Austria; Vorarlberg, fundort: Bregenzer Wald: Pfänder Gipfel, Alpengh. Fluh.

U.1542167	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Unknown; Europa, Oeral R. Alpen.
U.1541621	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Austria; Nordtirol, fundort: Zillertaler Alpen: Schwarzach Tal SW Gerlos, outerlage: Silikat.
U.1541812	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Unknown; Stiria media: in pratis prope pagun Stainz, solo schistoso.
U.1541777	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Denekamp, near the Dimbel Canal.
U.1541766	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; sandy road Glimmen–Oosterbrug, NW Canal.
U.1542463	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Poland; Polonica, forestreserve 'Swinia Gora', in the territory of Gory Swietokrzyskie (Holy Cross Mts.). North - West of Kielce.
U.1542469	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Unknown; Britain, speyside Scotland, damp meadow.
U.1542461	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Austria; Burgenland; Sieggraben, near Oedenburg (Hungarian Sopron).
L.4183805	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Unknown; flora of the Eifel. Duum, Eifel.
L.4183455	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Sweden; ± Lakolm, grassy.
L.4195116	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; France; forest road near Les Gras below Morteau, Doubs department.
L.4195755	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Norway; Apesland near Finsland (45 km N of Kristiansland).
L.4208039	*Alchemilla plicata* Buser	Naturalis Biodiversity Center	Europe; Norway; Kongsvoll, along the roadside.
L.4228533	*Alchemilla mollis* (Buser) Rothm.	Naturalis Biodiversity Center	Unknown; Afkomstig PPD Overijssel.
L.4228528	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; southeast of Beesel between Swalmen and Reuver. Amersfoort coordinates 201-363. In a ditch at Beeselsbroek. Haagweg. Along railway tracks. Coordinates 92-463. Grid square 30.37.23.
L.4228514	*Alchemilla mollis* (Buser) Rothm.	Naturalis Biodiversity Center	
AMD.104512	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Unknown; Termia, Ostrobotnia, Kajana, near Paus.
L.2074792	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Drenthe; Assen, De Haar.
L.2074791	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Drenthe; Assen, De Haar.
L.3962748	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Friesland; Kootsertille.
L.3962744	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Drenthe; Lheederzand, near the SBB office.
L.3962750	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Overijssel; riparian lands of the Meppelerdiep.
L.3962761	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Groningen; Ulrum.
L.3962790	*Alchemilla subcrenata* Buser	Naturalis Biodiversity Center	Europe; Netherlands; Friesland; Kloostertille.
L.3962759	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Groningen; northeast of Ulrum, along the N361.
L.3962757	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; North Holland; Amsterdam-Plantage.
L.4317183	*Alchemilla glabra* Neygenf.	Naturalis Biodiversity Center	Europe; Netherlands; Overijssel; Kan. Alm.-Nordhorn.
323136	*Alchemilla plicata* Buser	KRAM	Europe; Poland; Western Pomerania, Wierzbowo, forest beech stand.
323137	*Alchemilla plicata* Buser	KRAM	Europe; Poland; Pieniny Mountains, glades below Czertezik.
323138	*Alchemilla plicata* Buser	KRAM	Europe, Poland, Pieniny
323140	*Alchemilla plicata* Buser	KRAM	Europe; Poland; Sądeczyzna region, Radziejowa Range: meadow above Wielka Roztoka.
323141	*Alchemilla plicata* Buser	KRAM	Europe; Poland; Sądeczyzna region, Radziejowa Range: Mała Roztoka valley.
323143	*Alchemilla plicata* Buser	KRAM	Europe; Poland; High Tatras.
323144	*Alchemilla plicata* Buser	KRAM	Europe; Poland; High Tatras.
323145	*Alchemilla plicata* Buser	KRAM	Europe; Poland; Belianske Tatras, Kozi Grzbiet.
323146	*Alchemilla plicata* Buser	KRAM	Europe; Poland; Belianske Tatras.
323147	*Alchemilla plicata* Buser	KRAM	Europe; Slovakia; Belianske Tatras.
323148	*Alchemilla plicata* Buser	KRAM	Europe, Sweden,
323298	*Alchemilla mollis* (Buser) Rothm.	KRAM	Grace, ?
323415	*Alchemilla plicata* Buser	KRAM	Europe, Poland, Pieniny
323512	*Alchemilla propinqua* H.Lindb. ex Juz.	KRAM	Europe; Poland; Białystok Voivodeship, Grajewo County.
323514	*Alchemilla propinqua* H.Lindb. ex Juz.	KRAM	Europe; Poland; Masurian Lake District, Olsztyn, lawn.
323515	*Alchemilla propinqua* H.Lindb. ex Juz.	KRAM	Europe, Sweden, Varmland
323616	*Alchemilla monticola* Opiz	KRAM	Europe; Poland; Western Tatras, Hala Skupniowa, hay meadow.
323633	*Alchemilla monticola* Opiz	KRAM	Poland; Zakopane, Górne Bystre, meadow.
323728	*Alchemilla monticola* Opiz	KRAM	Europe; Poland; Karkonosze Mountains, grasslands.
325064	*Alchemilla monticola* Opiz	KRAM	Europe, UK, Meadow on drift over limestone, 1400ft., forest in Teesdale
328339	*Alchemilla plicata* Buser	KRAM	Europe; Poland; Wilczkowo near Szczecinek.

329303	*Alchemilla monticola* Opiz	KRAM	Europe; Poland; Western Tatras, Kopa Kondracka, limestone.
336488	*Alchemilla plicata* Buser	KRAM	Europe; Poland; Beskid Sądeski, Radziejowa Range, Palenica stream valley, Biała Woda.
3560	*Alchemilla monticola* Opiz	KRAM	Poland; Białowieża Forest, Zwierzyniec Forest District, compartment 474, SW corner, by the railway track.
57916	*Alchemilla monticola* Opiz	KRAM	Poland; Białowieża, Palace Park, meadow.
57972	*Alchemilla monticola* Opiz	KRAM	Poland; Białowieża, Palace Park, meadow.
60726	*Alchemilla monticola* Opiz	KRAM	Poland; Białowieża Forest, Ladzka Puszcza Forest District, Podborowisko, compartment 778C, meadow.
60970	*Alchemilla propinqua* H.Lindb. ex Juz.	KRAM	Europe; Poland; Białowieża Forest, Białowieża Forest District, compartment 499A, Grudki, timber yard.
60989	*Alchemilla plicata* Buser	KRAM	Europe; Poland; Białowieża Forest, Zwierzyniec Forest District, at the E edge of compartment 451D, meadow.
61029	*Alchemilla plicata* Buser	KRAM	Europe; Poland; Białowieża Forest, Białowieża Glade, at the E edge of compartment 399D, fertile meadow.
61045	*Alchemilla monticola* Opiz	KRAM	Poland; Białowieża Forest, Białowieża Glade, at the eastern edge of compartment 399D.
61986	*Alchemilla plicata* Buser	KRAM	Europe; Poland; Białowieża Forest, Białowieża Glade, Podolany, N of compartment 500B, meadow.
61987	*Alchemilla plicata* Buser	KRAM	Europe; Poland; Białowieża Forest, Białowieża Glade, Podolany, N of compartment 500B, meadow.
61995	*Alchemilla plicata* Buser	KRAM	Europe; Poland; Białowieża Forest, Białowieża Glade, at the S edge of compartment 399D, meadow.
62011	*Alchemilla plicata* Buser	KRAM	Europe; Poland; Białowieża Forest, Białowieża Glade, at the S edge of compartment 398D, meadow.
62020	*Alchemilla plicata* Buser	KRAM	Europe; Poland; Białowieża Forest, Białowieża Forest District, compartment 525D, storage yard by the forest railway - grassland.
62090	*Alchemilla propinqua* H.Lindb. ex Juz.	KRAM	Europe; Poland; Białowieża Forest, Hajnówka Forest District, compartments 242C/271A, by the road.
62127	*Alchemilla propinqua* H.Lindb. ex Juz.	KRAM	Europe; Poland; Białowieża Forest, Narewka Forest District, compartment 75A, storage yard by the railway.
62172	*Alchemilla propinqua* H.Lindb. ex Juz.	KRAM	Europe; Poland; Białowieża Forest, Hajnówka Forest District, compartment 244, timber yard by the railway.
62336	*Alchemilla propinqua* H.Lindb. ex Juz.	KRAM	Europe; Poland; Białowieża Forest, Zwierzyniec Forest District, compartment 420A, near the Zwierzyniec settlement.
62339	*Alchemilla propinqua* H.Lindb. ex Juz.	KRAM	Europe; Poland; Białowieża Forest, Hajnówka Forest District, compartment 307A, meadow by the Łutownia.
62346	*Alchemilla monticola* Opiz	KRAM	Poland; Białowieża Forest, Zwierzyniec Forest District, compartment 420A, near the Zwierzyniec settlement.
62348	*Alchemilla monticola* Opiz	KRAM	Poland; Białowieża Forest, Białowieża Glade, by the road SE of Pogorzelce.
62352	*Alchemilla propinqua* H.Lindb. ex Juz.	KRAM	Europe; Poland; Białowieża Forest, Białowieża Glade, E of Białowieża railway station, meadow beside the railway track.
62361	*Alchemilla monticola* Opiz	KRAM	Poland; Białowieża Forest, Dziedzinka, lawn.
62364	*Alchemilla propinqua* H.Lindb. ex Juz.	KRAM	Europe; Poland; Białowieża Forest, Białowieża Glade, N of Podolany, meadow beside the railway track.
66187	*Alchemilla monticola* Opiz	KRAM	Poland; Białowieża, Białowieża Glade, on a lawn.
BR0000005077571	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000006357207	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Arches (Vosges); alluvial plain of the Moselle, left bank, meadow, relevé 676.
BR0000006357405	*Alchemilla monticola* Opiz	Meise Botanic Garden	beach with Molinietum species in the meadow, which is generally rather dry, relevé 475.
BR0000006357443	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Eloie (Vosges); downstream of the village, right bank of the Moselle; relevé 672.
BR0000006357498	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Germany; Alendorf, municipality of Ripsdorf, east of Stadtkyll; Lamperstal Valley, meadow.
BR0000006357528	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Roville (Meurthe-et-Moselle)
BR0000006371265	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Doubs: Chapelle des Bois, on limestone rocks in forest.
BR0000006371272	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Vogesen, Honeck
BR0000006931254	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Switzerland; Valais: Montana - 'Bella L[uè]'
BR0000006931520	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Switzerland; Valais - S[t] Lu[c]: Val d'[Anneviers] - below 'Chalet Blanc' at 'Le Payon'.
BR0000008141354	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; mountain pasture at the foot of Rotenbach; Vosges (Route des Crêtes).
BR0000008141422	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; mountain pasture of Grand Ballon; Vosges.
BR0000008141439	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Switzerland; Saas Fee
BR0000009408838	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Jura: Jougne
BR0000009577824	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000009721616	*Alchemilla monticola* Opiz	Meise Botanic Garden	Bretterboden (SW of Grossgaepckner and E of Dorfer Tal, H of Kals) (Ost Tirol, Glockner Gruppe), N of Moaalm Hut, W-facing and
BR0000009916753	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Puy de la Vache
BR0000009916777	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Grand Ventron
BR0000009916845	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Route des Crêtes - [source] of the Moselotte; Fontaine de la Duchesse.
BR0000009916920	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; between Route des Crêtes and Breitfirst.
BR0000009916968	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Arches (Vosges); alluvial plain of the Moselle, left bank.
BR0000009917026	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; between La Lauch and Lautenbach.

BR0000009987630	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Italy; northern Italy: between Lago d'Iseo and Lago d'Idro, by chairlift above Collio, on limestone, forest edge.
BR0000009987647	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Italy; Alps, just below P° Gr. San Bernardo, grassy roadside verge.
BR0000009987678	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Germany; Munich Botanical Garden (Bavaria); Chiemgau Alps, Sachrang road, on Geigelstein (Bavaria).
BR0000010303894	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010303900	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010303955	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010303979	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010303993	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304006	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304013	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304020	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304099	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304112	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304129	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304174	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304273	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304280	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304303	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304310	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304433	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304464	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304501	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304570	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304594	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304617	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304624	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304679	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304730	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304778	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010304976	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000010929575	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000010929759	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000010930052	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000010930083	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000010971529	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000011093244	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000011093411	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000011093558	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000011093770	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000011093886	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000011094104	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000011094272	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000011094302	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000011094395	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000011094579	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000011094630	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000011094722	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000011094753	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;

BR0000011094784	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000011094845	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000011094937	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000011094968	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000011095088	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000011095118	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000011095170	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000011095378	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000011095385	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000011095415	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000011095644	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000011095910	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000011095972	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000011096061	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000011096153	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000011158059	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000012123278	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000012123377	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000012291076	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000012311989	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000012312023	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000012312047	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000012312061	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000012312115	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000012312122	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000012312139	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000012312153	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000012359721	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000012444038	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000012594511	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000012594818	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Belgium
BR0000012595082	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000012595181	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000012595389	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000012595488	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Belgium;
BR0000012595655	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000012595754	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium;
BR0000022438560	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Gerardmer (Vosges)
BR0000024647526	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Norway; W de Kragerö [= Kragerø]
BR0000024647564	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Bloie, Vosges department. Downstream of the village. Right bank of the Moselle.
BR0000025301946V	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Montenvers au-dessus de Chamonix
BR0000025301977V	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Italy; Faloria
BR0000025301991V	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Germany; Allgäu
BR0000025302011V	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Switzerland; San Bernardino, Graubünden
BR0000025302028V	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; ascent of Mont Céüse.
BR0000025302042V	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Italy; Toblach (Dobbiaco)
BR0000025302059V	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Italy; Faloria
BR0000025302066V	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Italy; Sellajoch, at the exit of Grödnertal coming from Wolkenstein.

BR0000025302110V	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; along the road from Lanslevillard to Mont Cenis.
BR0000025302288V	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; France; Ribon Valley, left of the road between Lanslevillard and Bessans.
BR0000025302295V	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; France; Col du Mont Cenis (Savoie)
BR0000025302332V	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Poland; Skałka Hill, a short distance from Ojców National Park, Kraków Voivodeship.
BR0000025635553V	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium; Muizenbos, on a little-used forest road.
BR0000026172668V	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Sweden; Östersund (Jämtland), Frösön, forets area between Valla and Frösö camping, N-margin of the residential area.
BR0000026172682V	*Alchemilla glaucescens* Wallr.	Meise Botanic Garden	Europe; Finland; Kisko [Vasinais-Suomi (V/Ab)], Marttila, ca 100 m WSW from Marttila farmhouse.
BR0000026172712V	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Switzerland; Varvallanna d'amont (Canton of Fribourg), in the Vallée de Motélon.
BR0000026271798V	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; France; road to Mont Cenis. Lanslevillard.
BR0000026273174V	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; France; Bois d'Aubrac (volcanic Aubrac massif SW of the Massif Central).
BR0000027433041V	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Switzerland; Saas Almagell (Canton of Valais), about 100 m from the municipal square and Hotel Portjengratt.
BR0000027433065V	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; France; Col du Mont - Cenis
BR0000027433072V	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; France; Col du Mont - Cenis
BR0000027433089V	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Austria; Untergurgl (Oetztaler Alpen)
BR0000027433096V	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium; surroundings of Dianant (Namur).
BR0000027464106V	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Switzerland; VD: Col des Essets. S Anzeindaz.
BR0000027739303V	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium; 't Hasselt (Bree)
BR0000031845236	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Finland; Kisko [Varsinais-Suomi (V/Ab)], Marttila, ca 150 m SW from Marttila farmhouse
BR0000031845250	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Arèches (Savoie), near Col du Pré, between the Roselend dam and Arèches.
BR0000031845267	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Gerardmer
BR0000031845274	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; surroundings of Gerardmer.
BR0000031845328	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Switzerland; Valais: Bagnes: Verbier - Station, [Dabonné]
BR0000031845458	*Alchemilla monticola* Opiz	Meise Botanic Garden	Slovenské Rudohorie Mountains: in the valley between the villages of Dedinky and Stratená, not far from Dobšiná.
BR0000031845526	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; Germany; National Botanic Garden of Belgium at Meise; provenance: Eifel, Irsen Valley.
BR0000031845533	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Vosges, meadows at Sapois, on granite.
BR0000031845540	*Alchemilla monticola* Opiz	Meise Botanic Garden	Europe; France; Courchevel (Savoie); road between Moriond and Courchevel.
BR0000036322763	*Alchemilla glabra* Neygenf.	Meise Botanic Garden	Europe; Belgium; Daverdisse, Lesse Valley upstream of 'Les Huttes', left bank, valley front.
E00093039	*Alchemilla glaucescens* Wallr.	RBGE	Europe; United Kingdom; Scotland; VC81 Berwickshire
E00093043	*Alchemilla monticola* Opiz	RBGE	Unknown
E00128233	*Alchemilla monticola* Opiz	RBGE	Europe; United Kingdom;
E00128235	*Alchemilla subcrenata* Buser	RBGE	Europe; United Kingdom; England;
E00128241	*Alchemilla glabra* Neygenf.	RBGE	Europe; Bulgaria
E00441087	*Alchemilla mollis* (Buser) Rothm.	RBGE	Europe; Turkey; Bitlis; Tatvan
E00441088	*Alchemilla mollis* (Buser) Rothm.	RBGE	Europe; Turkey; Kastamonu
E00441092	*Alchemilla mollis* (Buser) Rothm.	RBGE	Europe; Turkey; Sinop;
E00639970	*Alchemilla glaucescens* Wallr.	RBGE	Europe; United Kingdom; Scotland; VC108 West Sutherland
E00678057	*Alchemilla glabra* Neygenf.	RBGE	Unknown
E00678066	*Alchemilla glaucescens* Wallr.	RBGE	Unknown
E00678067	*Alchemilla glaucescens* Wallr.	RBGE	Unknown
E00678068	*Alchemilla glaucescens* Wallr.	RBGE	Unknown
E00678069	*Alchemilla glaucescens* Wallr.	RBGE	Unknown
E00678070	*Alchemilla glaucescens* Wallr.	RBGE	Unknown
E00678071	*Alchemilla glaucescens* Wallr.	RBGE	Unknown
E00678074	*Alchemilla glaucescens* Wallr.	RBGE	Unknown
E00678083	*Alchemilla mollis* (Buser) Rothm.	RBGE	Unknown
E00800254	*Alchemilla subcrenata* Buser	RBGE	Unknown
E00800447	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800451	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland

E00800452	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800453	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800454	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800456	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800459	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800464	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800465	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800466	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800467	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800469	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800475	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800480	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800481	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800482	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800485	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800486	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800487	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800491	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800494	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800495	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800496	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800497	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00800498	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829018	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829023	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829033	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829034	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829035	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829036	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829043	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829045	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829046	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829051	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829052	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829053	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829055	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829057	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829060	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829067	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829068	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829070	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829071	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829073	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829074	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829076	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829078	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829079	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829080	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland

E00829083	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829084	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829085	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829086	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829088	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829092	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829093	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829094	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829095	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829096	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829098	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829099	*Alchemilla glabra* Neygenf.	RBGE	Europe; United Kingdom; Scotland
E00829103	*Alchemilla mollis* (Buser) Rothm.	RBGE	Europe; United Kingdom; Scotland
E00829104	*Alchemilla mollis* (Buser) Rothm.	RBGE	Europe; United Kingdom; Scotland
E00829105	*Alchemilla mollis* (Buser) Rothm.	RBGE	Europe; United Kingdom; Scotland
E00829106	*Alchemilla mollis* (Buser) Rothm.	RBGE	Europe; United Kingdom; Scotland
E00829107	*Alchemilla mollis* (Buser) Rothm.	RBGE	Europe; United Kingdom; Scotland
E00829109	*Alchemilla mollis* (Buser) Rothm.	RBGE	Europe; United Kingdom; Scotland
E01153123	*Alchemilla glabra* Neygenf.	RBGE	Unknown
E01153124	*Alchemilla glabra* Neygenf.	RBGE	Unknown
E01153126	*Alchemilla glabra* Neygenf.	RBGE	Unknown
E01153127	*Alchemilla glabra* Neygenf.	RBGE	Unknown
E01153128	*Alchemilla glabra* Neygenf.	RBGE	Unknown
E01153131	*Alchemilla glabra* Neygenf.	RBGE	Unknown
E01153133	*Alchemilla glabra* Neygenf.	RBGE	Unknown
E01153135	*Alchemilla glabra* Neygenf.	RBGE	Unknown
E01153145	*Alchemilla glaucescens* Wallr.	RBGE	Unknown
E01153147	*Alchemilla glaucescens* Wallr.	RBGE	Unknown
E01153149	*Alchemilla glaucescens* Wallr.	RBGE	Unknown
E01153151	*Alchemilla glaucescens* Wallr.	RBGE	Unknown
E01153152	*Alchemilla glaucescens* Wallr.	RBGE	Unknown
E01153153	*Alchemilla glaucescens* Wallr.	RBGE	Unknown
E01153170	*Alchemilla propinqua* H.Lindb. ex Juz.	RBGE	Unknown
E01153213	*Alchemilla monticola* Opiz	RBGE	Unknown
E01153214	*Alchemilla monticola* Opiz	RBGE	Unknown
E01153215	*Alchemilla monticola* Opiz	RBGE	Unknown
E01153216	*Alchemilla monticola* Opiz	RBGE	Unknown
E01153218	*Alchemilla glaucescens* Wallr.	RBGE	Unknown
E01153219	*Alchemilla monticola* Opiz	RBGE	Unknown
E01153220	*Alchemilla monticola* Opiz	RBGE	Unknown
E01153221	*Alchemilla monticola* Opiz	RBGE	Unknown
E01153222	*Alchemilla monticola* Opiz	RBGE	Unknown
E01153223	*Alchemilla monticola* Opiz	RBGE	Unknown
E01153224	*Alchemilla monticola* Opiz	RBGE	Unknown
E01153225	*Alchemilla monticola* Opiz	RBGE	Unknown
E01153228	*Alchemilla monticola* Opiz	RBGE	Unknown
E01153229	*Alchemilla monticola* Opiz	RBGE	Unknown
E01153232	*Alchemilla monticola* Opiz	RBGE	Unknown

E01153251	*Alchemilla mollis* (Buser) Rothm.	RBGE	Unknown
E01153299	*Alchemilla monticola* Opiz	RBGE	Unknown
E01153312	*Alchemilla glaucescens* Wallr.	RBGE	Unknown
E01153327	*Alchemilla subcrenata* Buser	RBGE	Unknown
E01153328	*Alchemilla subcrenata* Buser	RBGE	Unknown
E01153329	*Alchemilla subcrenata* Buser	RBGE	Unknown
E01153330	*Alchemilla subcrenata* Buser	RBGE	Unknown
E01153333	*Alchemilla subcrenata* Buser	RBGE	Unknown
E01153335	*Alchemilla subcrenata* Buser	RBGE	Unknown
E01153336	*Alchemilla subcrenata* Buser	RBGE	Unknown
K000914197	*Alchemilla mollis* (Buser) Rothm.	Royal botanic garden Kew	United Kingdom; Kew Gardens; West Arboretum: shady banks in the Rhododendron Dell (zone 231)
KRAM 62190	*Alchemilla glaucescens* Wallr.	KRAM	Europe; Poland; Białowieża Forest, Białowieża Glade, at the south-western edge of compartment 339B, meadow.
KRAM00028870-V	*Alchemilla glaucescens* Wallr.	KRAM	Europe; Poland; Beskid Sądeski, Radziejowa Range, meadow.
KRAM00028872-V	*Alchemilla glaucescens* Wallr.	KRAM	Europe, Poland, unknown
KRAM00028878-V	*Alchemilla glaucescens* Wallr.	KRAM	Europe, Poland, unknown
KRAM00028880-V	*Alchemilla glaucescens* Wallr.	KRAM	Europe, France, unknown
KRAM304648	*Alchemilla glabra* Neygenf.	KRAM	Europe, Karawanken, unknown
KRAM323223	*Alchemilla glaucescens* Wallr.	KRAM	Europe; Poland; mountains, Western Tatras.
KRAM323233	*Alchemilla glaucescens* Wallr.	KRAM	Europe, Poland, unknown
KRAM323240	*Alchemilla glaucescens* Wallr.	KRAM	Europe; Poland; Sądeszczyzna region, Jaworzyna Range.
KRAM323266	*Alchemilla glabra* Neygenf.	KRAM	Europe; Poland; mountains, Western Tatras.
KRAM323272	*Alchemilla glabra* Neygenf.	KRAM	Europe, Poland, Kominy
KRAM323273	*Alchemilla glabra* Neygenf.	KRAM	Europe; Poland; Upper Silesia.
KRAM323275	*Alchemilla glabra* Neygenf.	KRAM	Europe; Poland; Lesser Poland Upland.
KRAM323448	*Alchemilla glabra* Neygenf.	KRAM	Europe; Poland; mountains, High Tatras.
KRAM323449	*Alchemilla glabra* Neygenf.	KRAM	Europe; Poland; mountains, Eastern Tatras.
KRAM323452	*Alchemilla glabra* Neygenf.	KRAM	Europe, Poland, unknown
KRAM323458	*Alchemilla glabra* Neygenf.	KRAM	Europe, Poland, mountains, Pieniny
KRAM323466	*Alchemilla glabra* Neygenf.	KRAM	Europe; Poland; Sądeszczyzna region.
KRAM323476	*Alchemilla glabra* Neygenf.	KRAM	Europe; Poland; Podtatrze region.
KRAM323480	*Alchemilla glabra* Neygenf.	KRAM	Europe; Poland; Podtatrze region - Zakopane.
KRAM328232	*Alchemilla glaucescens* Wallr.	KRAM	Jaworzyna Range, between Jaworzynka and Pusta Wielka, near Żegiestów-Zdrój, 720–800 m a.s.l.
KRAM329440	*Alchemilla glabra* Neygenf.	KRAM	Europe; Poland; Babia góra.
KRAM329446	*Alchemilla glabra* Neygenf.	KRAM	Europe, France, mountains, Alpes Maritines
KRAM329448	*Alchemilla glabra* Neygenf.	KRAM	Europe; Poland; southern Podtatrze region.
KRAM397299	*Alchemilla glabra* Neygenf.	KRAM	Europe; Poland; northern Sądeszczyzna region.
UGDA.0023974	*Alchemilla monticola* Opiz	UGDA	County, Bukowina, between Lębork and Sierakowice; Kashubian Landscape Park.
UGDA.0023982	*Alchemilla monticola* Opiz	UGDA	Poland; Pomeranian Voivodeship, Kashubian Lake District, Lębork County, Rzym, near Sianowo; Kashubian Landscape Park.
UGDA.0031237	*Alchemilla sp.*	UGDA	Poland; Pomeranian Voivodeship, Kashubian Lake District, Kartuzy County, Kartuzy, Asesora Promenade; CA-97.
UGDA.0033311	*Alchemilla monticola* Opiz	UGDA	"Przyjaźń" Nature Reserve in the Kashubian Lake District, near Żukowo, Skrzeszewo Forest Range, compartment 66 b2, c2.
UGDA.0033737	*Alchemilla pastoralis* Buser	UGDA	Gdańsk Voivodeship, Wejherowo Śmiechowo, Gdańska Street.
UGDA.0040839	*Alchemilla pastoralis* Buser	UGDA	Kashubian Lake District, Babi Dół, by the railway embankment toward Kartuzy, near the railway keeper's house.
UGDA.0040842	*Alchemilla glabra* Neygenf.	UGDA	Zagórska Struga, near the Piekiełko forester's lodge.
UGDA.0040925	*Alchemilla monticola* Opiz	UGDA	Poland; Pomeranian Voivodeship, Kierzkowo between Lubiatowo and Choczewo.
UGDA.0040926	*Alchemilla obtusa* Buser	UGDA	Poland; Lower Silesian Voivodeship, Jelenia Góra, "Sofal" ponds.
UGDA.0040927	*Alchemilla monticola* Opiz	UGDA	Poland; Lower Silesian Voivodeship, Grodziec Mały.
UGDA.0064213	*Alchemilla sp.*	UGDA	of the Dębowo settlement, peninsula west of the shore of Lake Gniazda.
UGDA.0087204	*Alchemilla sp.*	UGDA	Warmian-Masurian Voivodeship, Solanka, near Srokowo.

UGDA.0093434	*Alchemilla monticola* Opiz	UGDA	Poland; Kashubian Lake District, Nowa Huta, slope of the Łeba Valley, slope inclination approx. 15°.
UGDA.0093435	*Alchemilla monticola* Opiz	UGDA	Poland; Kashubian Lake District, Nowa Huta, slope of the Łeba Valley, slope inclination approx. 15°.
UGDA.0097304	*Alchemilla sp.*	UGDA	Poland; Pomeranian Voivodeship, Bytów County, Lipnica municipality, Rokitniki, on the southern side.
UGDA.0098982	*Alchemilla sp.*	UGDA	Poland; Podlaskie Voivodeship, Suwałki Landscape Park, "Rutka", Linówek locality.
UGDA.0098985	*Alchemilla sp.*	UGDA	Poland; Podlaskie Voivodeship, Suwałki Landscape Park, "Rutka", Linówek locality.
UGDA.0099046	*Alchemilla vulgaris* L.	UGDA	Kuyavian-Pomeranian Voivodeship, Kęsowo.
UGDA.0109002	*Alchemilla sp.*	UGDA	Poland; Pomeranian Voivodeship, Wejherowo County, Wejherowo, Wejherowo Forest District.
UGDA.0109005	*Alchemilla sp.*	UGDA	Poland; Pomeranian Voivodeship, vicinity of Przetoczyno.
UGDA.0109016	*Alchemilla sp.*	UGDA	Poland; Lower Silesian Voivodeship, Wrocław County, Czernica municipality, Chrząstawa Mała, Polna Street 17.
UGDA.0109019	*Alchemilla sp.*	UGDA	Poland; Lower Silesian Voivodeship, Wrocław County, Czernica municipality, Chrząstawa Mała, Polna Street 17.
UGDA.0114795	*Alchemilla sp.*	UGDA	Lipnica municipality, 1 km NNNW of the crossroads in Gliśno Wielkie village, on the E shore of Lake Przytarnia.
UGDA.0114796	*Alchemilla monticola* Opiz	UGDA	Pomeranian Voivodeship, Charzykowy Plain, Bytów County, Lipnica municipality, Łąkie.
UGDA.0114797	*Alchemilla sp.*	UGDA	Pomeranian Voivodeship, Wejherowo County, Szemud municipality, vicinity of Łebno.
UGDA.0114798	*Alchemilla acutiloba* Opiz	UGDA	County, Szemud, approx. 0.5 km NW of the church, behind the school.
UGDA.0114801	*Alchemilla sp.*	UGDA	County, Szemud municipality, Koleczkowo, 0.7 km W of the midpoint of the causeway between the Marchowo lakes.
UGDA.0114802	*Alchemilla sp.*	UGDA	County, Szemud municipality, Koleczkowo, 0.7 km W of the midpoint of the causeway between the Marchowo lakes.
UGDA.0114823	*Alchemilla sp.*	UGDA	Lipnica municipality, 1 km NE of the road bridge over the Kamienica, near Gliśno Wielkie.
UGDA.0114824	*Alchemilla sp.*	UGDA	Lipnica municipality, 1.25 km NEE of the road bridge over the Kamienica, near Gliśno Wielkie, on the western edge of a peatland
UGDA.0114826	*Alchemilla sp.*	UGDA	Pomeranian Voivodeship, Charzykowy Plain, Bytów County, Lipnica municipality, 0.3 km NE of the church in Łąkie.
UGDA.0114913	*Alchemilla sp.*	UGDA	municipality, 0.9 km SE of the church in Brzeźno Szlacheckie, at the end of Lake Gwieździniec.
UGDA.0128572	*Alchemilla vulgaris* L.	UGDA	s. loc.
UGDA.0137789	*Alchemilla hybrida* (L.) L.	UGDA	Badenweiler
UGDA.0139632	*Alchemilla vulgaris* L.	UGDA	Bertelsdorf
UGDA.0140624	*Alchemilla monticola* Opiz	UGDA	Poland; Kashubian Lake District, Rynarzewo.
UGDA.0141940	*Alchemilla sp.*	UGDA	County, 2.65 km NWW of the church in Szemud, beyond Bursztynowa Street, W of the Głazica gravel pit.
UGDA.0142522	*Alchemilla propinqua* H.Lindb.ex Juz.	UGDA	Miastko municipality, Dolsko, between Lake Dolskie and Lake Piasek.
UGDA.0142862	*Alchemilla acutiloba* Opiz	UGDA	Pomeranian Voivodeship, Charzykowy Plain, Bytów County, Lipnica municipality, Borowy Młyn, approx. 0.5 km W of the village.
UGDA.0143251	*Alchemilla pastoralis* Buser	UGDA	Kashubian Lake District, Staniszewo Upland, Miechucino, Łeba Valley.
UGDA.0173451	*Alchemilla sp.*	UGDA	Poland; vicinity of Teleśnica Oszwarowa.
UGDA.0180955	*Alchemilla vulgaris* L.	UGDA	Germany; Martinfeld / Eichsf.
UGDA.0201600	*Alchemilla pastoralis* Buser	UGDA	Austria; Styria, Ennstal Alps, Tamischbachturm, approx. 2000 m a.s.l.
UGDA.0215379	*Alchemilla sp.*	UGDA	Pomeranian Voivodeship, Załakowo, vicinity of Lake Okonko.
UGDA.0237565	*Alchemilla pastoralis* Buser	UGDA	Kashubian Lake District, 0.2 km SWW of Ząbrze Małe, southern shore of Lake Ząbrsko Małe.
UGDA.0237575	*Alchemilla pastoralis* Buser	UGDA	Poland; Pomeranian Voivodeship, Gdańsk, Klukowo.
UGDA.0237583	*Alchemilla pastoralis* Buser	UGDA	Kashubian Lake District, Oliwa Forest District, Matemblewo Forest Range, compartment 92.
UGDA.0237584	*Alchemilla propinqua* H.Lindb.ex Juz.	UGDA	Kashubian Lake District, Oliwa Forest District, Matemblewo Forest Range, compartment 92.
UGDA.0240211	*Alchemilla sp.*	UGDA	Pomeranian Voivodeship, Wejherowo, road out toward Kąpino.
UGDA.0240217	*Alchemilla sp.*	UGDA	Poland; Pomeranian Voivodeship, University of Gdańsk campus, Wita Stwosza Street, opposite the University of Gdańsk Library.

Supplementary Table S2. Specimen-level principal component analysis (PCA) scores and mean morphometric shape descriptors of leaves in the examined *Alchemilla* taxa.

Supplementary Table S2. Specimen-level principal component analysis (PCA) scores and mean morphometric shape descriptors of leaves in the examined *Alchemilla* taxa.

A. Specimen-level PC1 and PC2 scores and mean leaf shape descriptors

Specimen number	Species	No. of leaves averaged	PC1	PC2	Circularity	Aspect ratio	Roundness	Solidity
WAG.1561156	Alchemilla glabra Neygenf.	1	-0.048456	0.021262	0.332000	1.355000	0.738000	0.799000
WAG.1503755	Alchemilla mollis (Buser) Rothm.	1	0.019329	0.069226	0.282000	1.313000	0.762000	0.871000
WAG.1503792	Alchemilla propinqua H.Lindb. ex Juz.	1	0.168469	0.045023	0.370000	1.247000	0.802000	0.891000
WAG.1503754	Alchemilla mollis (Buser) Rothm.	1	0.156047	-0.037699	0.308000	1.169000	0.855000	0.912000
WAG.1503812	Alchemilla subcrenata Buser	1	0.160850	0.006116	0.325000	1.217000	0.822000	0.906000
L.1888231	Alchemilla subcrenata Buser	1	-0.013409	0.096457	0.268000	1.278000	0.782000	0.837000
L.1889332	Alchemilla glabra Neygenf.	1	-0.016928	0.170906	0.273000	1.221000	0.819000	0.760000
L.1889323	Alchemilla glabra Neygenf.	1	-0.000483	0.049416	0.397000	1.339000	0.747000	0.843000
L.1889090	Alchemilla plicata Buser	1	0.045583	0.009183	0.245000	1.299000	0.770000	0.834000
L.1889097	Alchemilla plicata Buser	2	-0.041731	-0.004293	0.295000	1.337500	0.748500	0.816000
L.1889318	Alchemilla glabra Neygenf.	1	-0.021287	-0.063737	0.324000	1.365000	0.733000	0.818000
L.1888237	Alchemilla subcrenata Buser	3	0.120817	-0.052167	0.254333	1.258333	0.798667	0.850667
L.1889317	Alchemilla glabra Neygenf.	1	-0.085192	-0.009544	0.385000	1.448000	0.691000	0.794000
L.1889096	Alchemilla plicata Buser	3	-0.008910	-0.050541	0.289667	1.325667	0.755000	0.842333
L.1889095	Alchemilla plicata Buser	2	-0.011464	-0.014759	0.267500	1.381000	0.726000	0.818000
L.1889326	Alchemilla glabra Neygenf.	1	-0.032654	-0.110808	0.316000	1.451000	0.689000	0.776000
L.1888234	Alchemilla subcrenata Buser	1	0.156060	0.015434	0.294000	1.179000	0.848000	0.838000
L.1889320	Alchemilla glabra Neygenf.	1	-0.042142	-0.021926	0.445000	1.380000	0.725000	0.836000
L.1889093	Alchemilla plicata Buser	4	-0.099859	-0.027943	0.290000	1.492500	0.670500	0.822250
L.1888235	Alchemilla subcrenata Buser	2	0.011822	-0.011166	0.314000	1.384000	0.723000	0.821500
L.1888240	Alchemilla subcrenata Buser	3	0.046438	0.004288	0.207000	1.354000	0.746333	0.679000
L.1889102	Alchemilla propinqua H.Lindb. ex Juz.	2	-0.030615	-0.051878	0.337000	1.388000	0.721500	0.853000
L.3260878	Alchemilla glabra Neygenf.	1	0.034359	-0.030537	0.357000	1.245000	0.803000	0.799000
L.3260066	Alchemilla glabra Neygenf.	1	-0.119945	0.048205	0.318000	1.414000	0.707000	0.822000
L.3260145	Alchemilla glabra Neygenf.	1	-0.044628	0.076030	0.313000	1.331000	0.751000	0.783000
L.3260194	Alchemilla glabra Neygenf.	1	-0.053746	-0.069940	0.385000	1.689000	0.592000	0.869000
L.3260013	Alchemilla glabra Neygenf.	2	-0.061103	0.006860	0.344000	1.432500	0.700500	0.834500
L.3249939	Alchemilla glabra Neygenf.	1	-0.114562	-0.001896	0.305000	1.422000	0.703000	0.771000
L.3260105	Alchemilla glabra Neygenf.	1	-0.112874	-0.016740	0.451000	1.507000	0.664000	0.842000
L.3260021	Alchemilla glabra Neygenf.	2	0.031653	-0.039601	0.207500	1.453000	0.691000	0.636500
L.3249853	Alchemilla mollis (Buser) Rothm.	1	0.179471	0.023306	0.376000	1.133000	0.883000	0.882000
L.3260170	Alchemilla glabra Neygenf.	3	-0.176408	0.008679	0.284667	1.483333	0.677000	0.807000
L.3260053	Alchemilla glabra Neygenf.	1	0.040359	0.067791	0.286000	1.245000	0.803000	0.860000
L.3260177	Alchemilla glabra Neygenf.	3	0.061135	-0.047439	0.264000	1.338667	0.749333	0.751000
L.3260161	Alchemilla glabra Neygenf.	1	-0.033878	0.010595	0.388000	1.263000	0.791000	0.815000
L.3260094	Alchemilla glabra Neygenf.	1	-0.122833	-0.042722	0.009000	1.292000	0.774000	0.497000
L.3260204	Alchemilla glabra Neygenf.	1	0.041235	0.024401	0.020000	1.328000	0.753000	0.503000
L.3249961	Alchemilla glabra Neygenf.	1	-0.022392	-0.044298	0.333000	1.372000	0.729000	0.776000
L.3260030	Alchemilla glabra Neygenf.	1	-0.007852	0.154636	0.274000	1.105000	0.905000	0.818000
L.3249894	Alchemilla subcrenata Buser	1	0.112011	-0.011724	0.234000	1.182000	0.846000	0.801000
L.3260168	Alchemilla glabra Neygenf.	1	0.062375	0.042049	0.286000	1.265000	0.790000	0.801000
L.3260027	Alchemilla glabra Neygenf.	2	-0.049823	-0.064148	0.320500	1.445000	0.692000	0.796500
L.3260104	Alchemilla glabra Neygenf.	1	-0.070390	0.038612	0.297000	1.304000	0.767000	0.808000
L.3260069	Alchemilla glabra Neygenf.	1	-0.173289	-0.002790	0.356000	1.474000	0.678000	0.833000
L.3249992	Alchemilla glabra Neygenf.	1	0.020141	0.128093	0.300000	1.231000	0.813000	0.836000
L.3260067	Alchemilla glabra Neygenf.	1	-0.107068	0.104200	0.258000	1.244000	0.804000	0.797000
L.3260076	Alchemilla glabra Neygenf.	1	-0.094507	0.122200	0.314000	1.242000	0.805000	0.812000
L.3260071	Alchemilla glabra Neygenf.	1	-0.125769	-0.058117	0.312000	1.346000	0.743000	0.836000
L.3249952	Alchemilla glabra Neygenf.	1	-0.116459	0.067020	0.298000	1.329000	0.752000	0.772000
L.3260127	Alchemilla glabra Neygenf.	1	-0.091332	0.019205	0.344000	1.416000	0.706000	0.794000
L.3249960	Alchemilla glabra Neygenf.	2	-0.060602	-0.028617	0.308000	1.311000	0.763000	0.785500
L.3260169	Alchemilla glabra Neygenf.	3	-0.129335	0.039020	0.302000	1.373000	0.729333	0.779333
L.3249895	Alchemilla subcrenata Buser	1	0.094650	-0.024626	0.277000	1.186000	0.843000	0.773000
L.3249923	Alchemilla glabra Neygenf.	2	-0.124975	0.033849	0.371000	1.310000	0.763500	0.845000
L.3260072	Alchemilla glabra Neygenf.	1	-0.056893	-0.029703	0.309000	1.317000	0.759000	0.751000
L.3260009	Alchemilla glabra Neygenf.	1	-0.150749	0.012116	0.343000	1.511000	0.662000	0.806000
L.3260151	Alchemilla glabra Neygenf.	2	-0.046412	-0.028719	0.361500	1.361500	0.734500	0.808500
L.3249956	Alchemilla glabra Neygenf.	1	0.045507	0.055008	0.365000	1.174000	0.852000	0.795000
L.3249980	Alchemilla glabra Neygenf.	1	-0.058153	-0.012050	0.350000	1.336000	0.749000	0.847000
L.3249889	Alchemilla subcrenata Buser	2	0.143957	0.012998	0.135500	1.158500	0.864000	0.677500
L.3260149	Alchemilla glabra Neygenf.	1	-0.048866	0.060674	0.298000	1.324000	0.755000	0.802000
L.3260016	Alchemilla glabra Neygenf.	1	-0.005961	0.153836	0.294000	1.212000	0.825000	0.792000
L.3260196	Alchemilla glabra Neygenf.	1	-0.114225	-0.037143	0.291000	1.398000	0.716000	0.809000
L.3260209	Alchemilla glabra Neygenf.	3	-0.063916	0.034494	0.279000	1.375333	0.728000	0.838667
L.3260119	Alchemilla glabra Neygenf.	1	0.031554	0.109976	0.380000	1.250000	0.800000	0.843000
L.3260188	Alchemilla glabra Neygenf.	1	-0.067488	0.046985	0.288000	1.484000	0.674000	0.812000
L.3260159	Alchemilla glabra Neygenf.	1	0.051564	0.093490	0.260000	1.188000	0.842000	0.837000
L.3260125	Alchemilla glabra Neygenf.	1	-0.058950	-0.118165	0.283000	1.455000	0.687000	0.795000
L.3249986	Alchemilla glabra Neygenf.	2	0.009785	-0.000868	0.291000	1.236500	0.810000	0.828000
L.3260122	Alchemilla glabra Neygenf.	1	0.119308	0.024736	0.287000	1.223000	0.818000	0.821000
L.3249959	Alchemilla glabra Neygenf.	1	-0.005489	0.061448	0.369000	1.308000	0.764000	0.861000
L.3260008	Alchemilla glabra Neygenf.	2	-0.074706	-0.011838	0.358500	1.454000	0.690500	0.848500
L.3260150	Alchemilla glabra Neygenf.	1	0.059737	0.127010	0.245000	1.166000	0.857000	0.843000
L.3260186	Alchemilla glabra Neygenf.	1	0.059390	0.106301	0.344000	1.277000	0.783000	0.821000
L.3260157	Alchemilla glabra Neygenf.	1	0.110657	-0.078273	0.312000	1.189000	0.841000	0.864000
L.3260062	Alchemilla glabra Neygenf.	2	-0.105724	0.022609	0.290500	1.410500	0.713000	0.814000
L.3260190	Alchemilla glabra Neygenf.	1	0.016510	0.101034	0.287000	1.198000	0.835000	0.773000
L.3249997	Alchemilla glabra Neygenf.	1	-0.130285	-0.012868	0.406000	1.520000	0.658000	0.881000
L.3249862	Alchemilla mollis (Buser) Rothm.	1	0.162430	-0.028007	0.427000	1.202000	0.832000	0.905000
L.3260101	Alchemilla glabra Neygenf.	1	-0.198105	0.022787	0.205000	1.380000	0.724000	0.838000
L.3260088	Alchemilla glabra Neygenf.	2	-0.099644	-0.014935	0.276500	1.443500	0.694000	0.776000
L.3249973	Alchemilla glabra Neygenf.	1	0.170044	-0.033289	0.289000	1.161000	0.861000	0.848000
L.3249857	Alchemilla mollis (Buser) Rothm.	2	0.135725	-0.011904	0.187000	1.690500	0.647000	0.653500
L.3260022	Alchemilla glabra Neygenf.	1	-0.037503	-0.043163	0.280000	1.407000	0.710000	0.769000

L.3249888	Alchemilla subcrenata Buser	1	0.026417	0.217302	0.348000	1.161000	0.861000	0.851000
L.3260173	Alchemilla glabra Neygenf.	1	0.180809	-0.067220	0.284000	1.131000	0.884000	0.800000
U.1541786	Alchemilla glabra Neygenf.	1	-0.193856	0.025165	0.284000	1.356000	0.737000	0.804000
U.1541617	Alchemilla glabra Neygenf.	1	-0.044303	0.005024	0.009000	1.878000	0.532000	0.493000
U.1542452	Alchemilla subcrenata Buser	2	0.063126	0.024467	0.313000	1.332500	0.751000	0.835000
U.1542453	Alchemilla subcrenata Buser	2	0.123347	-0.058272	0.279000	1.288000	0.777500	0.859000
U.1541616	Alchemilla glabra Neygenf.	2	-0.043169	0.044731	0.310500	1.410500	0.709500	0.802000
U.1541618	Alchemilla glabra Neygenf.	1	0.158802	-0.020271	0.287000	1.224000	0.817000	0.815000
U.1542167	Alchemilla glabra Neygenf.	1	0.035223	-0.107377	0.245000	1.246000	0.803000	0.820000
U.1541621	Alchemilla glabra Neygenf.	3	-0.016448	0.046183	0.233333	1.709667	0.622000	0.699000
U.1541812	Alchemilla glabra Neygenf.	1	-0.013529	-0.002108	0.428000	1.444000	0.693000	0.887000
U.1541777	Alchemilla glabra Neygenf.	1	-0.068602	0.011788	0.297000	1.312000	0.762000	0.787000
U.1541766	Alchemilla glabra Neygenf.	2	-0.111812	0.015859	0.163500	1.475500	0.678000	0.680000
U.1542463	Alchemilla glabra Neygenf.	1	0.069629	0.003787	0.291000	1.364000	0.733000	0.791000
U.1542469	Alchemilla glabra Neygenf.	1	-0.016195	0.116263	0.300000	1.212000	0.825000	0.827000
U.1542461	Alchemilla glabra Neygenf.	1	0.012531	-0.061123	0.400000	1.393000	0.718000	0.826000
L.4183805	Alchemilla glabra Neygenf.	3	0.076738	0.018687	0.298000	1.194333	0.837667	0.851667
L.4183455	Alchemilla glabra Neygenf.	1	0.075263	-0.009692	0.301000	1.208000	0.828000	0.840000
L.4195116	Alchemilla glabra Neygenf.	1	0.032604	0.069814	0.302000	1.169000	0.855000	0.814000
L.4195755	Alchemilla glabra Neygenf.	1	-0.062317	-0.012392	0.243000	1.439000	0.695000	0.748000
L.4208039	Alchemilla plicata Buser	2	0.059830	0.026961	0.291000	1.288000	0.776500	0.840000
L.4228533	Alchemilla mollis (Buser) Rothm.	1	-0.118615	0.042637	0.283000	1.344000	0.744000	0.879000
L.4228528	Alchemilla glabra Neygenf.	1	-0.079280	0.070240	0.343000	1.326000	0.754000	0.796000
L.4228514	Alchemilla mollis (Buser) Rothm.	1	-0.033799	0.023762	0.393000	1.311000	0.763000	0.898000
AMD.104512	Alchemilla glabra Neygenf.	3	0.093096	0.004986	0.151000	1.175667	0.851667	0.736333
L.2074792	Alchemilla glabra Neygenf.	2	-0.040453	-0.048044	0.322000	1.356500	0.737500	0.815500
L.2074791	Alchemilla glabra Neygenf.	1	-0.245946	-0.027208	0.350000	1.510000	0.662000	0.844000
L.3962748	Alchemilla glabra Neygenf.	1	-0.033308	-0.019441	0.354000	1.499000	0.667000	0.799000
L.3962744	Alchemilla glabra Neygenf.	1	-0.060373	-0.025725	0.457000	1.452000	0.689000	0.842000
L.3962750	Alchemilla glabra Neygenf.	1	-0.094564	0.049093	0.343000	1.423000	0.703000	0.835000
L.3962761	Alchemilla glabra Neygenf.	1	0.013811	-0.075163	0.393000	1.437000	0.696000	0.835000
L.3962790	Alchemilla subcrenata Buser	3	0.010004	-0.041910	0.367667	1.367000	0.733333	0.825333
L.3962759	Alchemilla glabra Neygenf.	1	-0.083013	0.015768	0.335000	1.484000	0.674000	0.818000
L.3962757	Alchemilla glabra Neygenf.	1	0.102981	-0.029887	0.286000	1.196000	0.836000	0.840000
L.4317183	Alchemilla glabra Neygenf.	1	-0.039959	0.039485	0.276000	1.344000	0.744000	0.825000
323136	Alchemilla plicata Buser	2	-0.089015	0.055483	0.127000	1.377500	0.729000	0.680500
323137	Alchemilla plicata Buser	2	-0.074503	-0.021582	0.232000	1.431500	0.698500	0.831500
323138	Alchemilla plicata Buser	8	-0.143843	-0.057011	0.257500	1.454750	0.693375	0.713500
323140	Alchemilla plicata Buser	1	-0.148447	-0.034671	0.282000	1.553000	0.644000	0.853000
323141	Alchemilla plicata Buser	3	-0.068733	-0.043858	0.301000	1.467000	0.684667	0.847000
323143	Alchemilla plicata Buser	3	-0.062232	-0.028056	0.313667	1.336000	0.748667	0.862000
323144	Alchemilla plicata Buser	3	0.009037	-0.060876	0.299000	1.385667	0.722333	0.844000
323145	Alchemilla plicata Buser	3	-0.011732	-0.055763	0.263000	1.390333	0.726333	0.846333
323146	Alchemilla plicata Buser	3	-0.065901	-0.057074	0.329667	1.457667	0.686333	0.857000
323147	Alchemilla plicata Buser	1	-0.188170	-0.023394	0.224000	1.532000	0.653000	0.828000
323148	Alchemilla plicata Buser	4	-0.018838	-0.022081	0.234250	1.404000	0.713750	0.817750
323298	Alchemilla mollis (Buser) Rothm.	1	0.012554	-0.065583	0.047000	1.145000	0.873000	0.310000
323415	Alchemilla plicata Buser	2	-0.102165	-0.037183	0.336500	1.479500	0.676000	0.854500
323512	Alchemilla propinqua H.Lindb. ex Juz.	1	-0.010507	-0.118519	0.270000	1.197000	0.835000	0.347000
323514	Alchemilla propinqua H.Lindb. ex Juz.	1	0.074918	0.003605	0.051000	1.044000	0.958000	0.345000
323515	Alchemilla propinqua H.Lindb. ex Juz.	2	0.058759	0.021317	0.256000	1.108000	0.904000	0.328000
323616	Alchemilla monticola Opiz	3	-0.044026	0.048678	0.298667	1.306000	0.766000	0.808667
323633	Alchemilla monticola Opiz	1	0.015517	-0.108872	0.285000	1.226000	0.815000	0.808000
323728	Alchemilla monticola Opiz	2	0.124320	-0.036857	0.257000	1.173000	0.853000	0.832500
325064	Alchemilla monticola Opiz	2	0.027833	-0.001064	0.257000	1.203000	0.832000	0.784500
328339	Alchemilla plicata Buser	1	-0.075129	0.035072	0.007000	1.524000	0.656000	0.305000
329303	Alchemilla monticola Opiz	1	0.121301	0.107485	0.275000	1.089000	0.919000	0.841000
336488	Alchemilla plicata Buser	7	-0.088496	-0.007233	0.286429	1.453143	0.690429	0.836429
3560	Alchemilla monticola Opiz	1	0.011727	0.070762	0.326000	1.215000	0.823000	0.831000
57916	Alchemilla monticola Opiz	1	0.106980	-0.091501	0.249000	1.196000	0.836000	0.807000
57972	Alchemilla monticola Opiz	2	0.115714	-0.080939	0.310000	1.295000	0.772000	0.809000
60726	Alchemilla monticola Opiz	1	0.140872	0.019251	0.238000	1.170000	0.855000	0.836000
60970	Alchemilla propinqua H.Lindb. ex Juz.	2	0.062398	0.076309	0.162000	1.223500	0.825500	0.462500
60989	Alchemilla plicata Buser	1	-0.018432	0.011940	0.199000	1.301000	0.769000	0.802000
61029	Alchemilla plicata Buser	2	0.062460	0.032241	0.203500	1.280000	0.785000	0.810000
61045	Alchemilla monticola Opiz	1	-0.031332	0.038106	0.264000	1.258000	0.795000	0.811000
61986	Alchemilla plicata Buser	1	-0.003135	0.024154	0.278000	1.383000	0.723000	0.866000
61987	Alchemilla plicata Buser	1	0.004603	0.092227	0.204000	1.221000	0.819000	0.817000
61995	Alchemilla plicata Buser	1	-0.096922	-0.044800	0.003000	1.518000	0.659000	0.405000
62011	Alchemilla plicata Buser	1	-0.007533	0.065828	0.164000	1.373000	0.729000	0.819000
62020	Alchemilla plicata Buser	1	-0.154686	0.041022	0.008000	2.356000	0.425000	0.279000
62090	Alchemilla propinqua H.Lindb. ex Juz.	2	0.095129	-0.009883	0.252000	1.285500	0.778500	0.854000
62127	Alchemilla propinqua H.Lindb. ex Juz.	1	-0.002748	-0.078028	0.053000	1.058000	0.946000	0.331000
62172	Alchemilla propinqua H.Lindb. ex Juz.	3	0.027723	0.013731	0.262333	1.185333	0.850333	0.666667
62336	Alchemilla propinqua H.Lindb. ex Juz.	2	0.042988	0.007299	0.327000	1.295500	0.772500	0.860500
62339	Alchemilla propinqua H.Lindb. ex Juz.	1	0.169374	-0.002092	0.227000	1.172000	0.853000	0.857000
62346	Alchemilla monticola Opiz	1	-0.017394	-0.021484	0.346000	1.442000	0.694000	0.830000
62348	Alchemilla monticola Opiz	1	0.089907	-0.018587	0.302000	1.228000	0.814000	0.829000
62352	Alchemilla propinqua H.Lindb. ex Juz.	1	0.064658	0.028725	0.307000	1.318000	0.759000	0.831000
62361	Alchemilla monticola Opiz	1	0.041755	0.033930	0.307000	1.221000	0.819000	0.821000
62364	Alchemilla propinqua H.Lindb. ex Juz.	1	0.077188	-0.092222	0.005000	1.314000	0.761000	0.462000
66187	Alchemilla monticola Opiz	2	-0.067144	-0.058181	0.353000	1.452000	0.689000	0.826000
BR0000005077571	Alchemilla glabra Neygenf.	1	0.020408	-0.025208	0.299000	1.403000	0.713000	0.815000
BR0000006357207	Alchemilla monticola Opiz	1	-0.045439	-0.052577	0.300000	1.385000	0.722000	0.811000
BR0000006357405	Alchemilla monticola Opiz	2	0.012411	0.061109	0.220000	1.231000	0.822000	0.828500
BR0000006357443	Alchemilla monticola Opiz	1	-0.101446	-0.014105	0.012000	1.318000	0.759000	0.543000
BR0000006357498	Alchemilla monticola Opiz	1	0.010344	0.202897	0.242000	1.107000	0.903000	0.821000
BR0000006357528	Alchemilla monticola Opiz	1	0.092010	-0.021132	0.235000	1.153000	0.867000	0.832000
BR0000006371265	Alchemilla monticola Opiz	2	-0.009482	-0.012804	0.210500	1.279500	0.789000	0.805000
BR0000006371272	Alchemilla monticola Opiz	2	0.051143	0.059464	0.107000	1.260500	0.795000	0.589500
BR0000006931254	Alchemilla monticola Opiz	2	0.044304	0.026230	0.239000	1.236000	0.809000	0.851500
BR0000006931520	Alchemilla monticola Opiz	2	-0.078063	-0.009802	0.260500	1.369000	0.731500	0.786000
BR0000008141354	Alchemilla monticola Opiz	1	-0.010139	0.047692	0.300000	1.307000	0.765000	0.795000
BR0000008141422	Alchemilla monticola Opiz	1	0.001002	-0.004840	0.339000	1.410000	0.709000	0.816000

BR0000008141439	Alchemilla monticola Opiz	1	0.083702	0.036602	0.221000	1.195000	0.837000	0.797000
BR0000009408838	Alchemilla monticola Opiz	1	0.061219	-0.092271	0.330000	1.347000	0.743000	0.835000
BR0000009577824	Alchemilla glabra Neygenf.	1	-0.149366	-0.036365	0.372000	1.460000	0.685000	0.871000
BR0000009721616	Alchemilla monticola Opiz	3	0.011959	-0.017802	0.225333	1.245333	0.804333	0.795333
BR0000009916753	Alchemilla monticola Opiz	1	0.011566	-0.042645	0.215000	1.365000	0.733000	0.775000
BR0000009916777	Alchemilla monticola Opiz	3	0.049044	-0.032693	0.285667	1.293667	0.773333	0.836000
BR0000009916845	Alchemilla monticola Opiz	1	0.086581	0.141895	0.276000	1.134000	0.882000	0.849000
BR0000009916920	Alchemilla monticola Opiz	1	-0.018503	0.085949	0.294000	1.248000	0.801000	0.802000
BR0000009916968	Alchemilla monticola Opiz	1	-0.111436	0.012912	0.330000	1.322000	0.757000	0.816000
BR0000009917026	Alchemilla monticola Opiz	2	0.004367	-0.015819	0.279000	1.292500	0.775000	0.825000
BR0000009987630	Alchemilla monticola Opiz	1	-0.008397	-0.088724	0.014000	1.264000	0.791000	0.335000
BR0000009987647	Alchemilla monticola Opiz	1	-0.017377	0.022160	0.224000	1.266000	0.790000	0.775000
BR0000009987678	Alchemilla monticola Opiz	1	0.043313	0.003435	0.229000	1.262000	0.793000	0.765000
BR0000010303894	Alchemilla glabra Neygenf.	1	0.074852	0.061388	0.266000	1.287000	0.777000	0.791000
BR0000010303900	Alchemilla glabra Neygenf.	1	-0.043684	0.062655	0.234000	1.297000	0.771000	0.786000
BR0000010303955	Alchemilla glabra Neygenf.	2	-0.095272	-0.030023	0.319000	1.422000	0.705500	0.816500
BR0000010303979	Alchemilla glabra Neygenf.	1	-0.062333	0.029391	0.253000	1.286000	0.778000	0.789000
BR0000010303993	Alchemilla glabra Neygenf.	1	-0.128098	-0.050286	0.439000	1.514000	0.660000	0.889000
BR0000010304006	Alchemilla glabra Neygenf.	2	-0.012560	0.006922	0.324500	1.330000	0.752000	0.810000
BR0000010304013	Alchemilla glabra Neygenf.	1	0.044767	-0.091945	0.382000	1.118000	0.895000	0.490000
BR0000010304020	Alchemilla glabra Neygenf.	1	-0.026229	-0.085249	0.462000	1.347000	0.742000	0.841000
BR0000010304099	Alchemilla glabra Neygenf.	1	0.003163	-0.001132	0.301000	1.285000	0.778000	0.793000
BR0000010304112	Alchemilla glabra Neygenf.	1	-0.005952	-0.121705	0.304000	1.319000	0.758000	0.835000
BR0000010304129	Alchemilla glabra Neygenf.	2	-0.102446	0.005222	0.301000	1.414000	0.707500	0.812000
BR0000010304174	Alchemilla glabra Neygenf.	1	0.030196	0.044258	0.003000	1.394000	0.717000	0.293000
BR0000010304273	Alchemilla glabra Neygenf.	1	0.041915	-0.034311	0.299000	1.210000	0.827000	0.820000
BR0000010304280	Alchemilla glabra Neygenf.	1	0.137130	-0.003631	0.282000	1.151000	0.869000	0.822000
BR0000010304303	Alchemilla glabra Neygenf.	1	-0.118254	0.058010	0.339000	1.418000	0.705000	0.837000
BR0000010304310	Alchemilla glabra Neygenf.	1	0.021608	-0.082525	0.216000	1.309000	0.764000	0.729000
BR0000010304433	Alchemilla glabra Neygenf.	1	-0.034830	0.004973	0.326000	1.353000	0.739000	0.784000
BR0000010304464	Alchemilla glabra Neygenf.	1	-0.110951	0.052348	0.294000	1.422000	0.703000	0.787000
BR0000010304501	Alchemilla glabra Neygenf.	1	-0.099698	-0.036571	0.264000	1.393000	0.718000	0.773000
BR0000010304570	Alchemilla glabra Neygenf.	1	-0.091943	0.048460	0.319000	1.398000	0.715000	0.776000
BR0000010304594	Alchemilla glabra Neygenf.	1	0.008215	-0.023748	0.351000	1.320000	0.757000	0.821000
BR0000010304617	Alchemilla glabra Neygenf.	1	-0.093885	0.059353	0.280000	1.407000	0.711000	0.770000
BR0000010304624	Alchemilla glabra Neygenf.	1	0.013405	0.064047	0.322000	1.324000	0.756000	0.818000
BR0000010304679	Alchemilla glabra Neygenf.	1	0.009491	-0.033267	0.247000	1.239000	0.807000	0.818000
BR0000010304730	Alchemilla glabra Neygenf.	1	-0.184345	-0.052061	0.238000	1.459000	0.686000	0.784000
BR0000010304778	Alchemilla glabra Neygenf.	1	-0.133386	-0.036904	0.331000	1.484000	0.674000	0.817000
BR0000010304976	Alchemilla glabra Neygenf.	1	-0.137443	-0.058270	0.028000	1.404000	0.712000	0.566000
BR0000010929575	Alchemilla glaucescens Wallr.	1	-0.068823	0.071697	0.198000	1.283000	0.780000	0.832000
BR0000010929759	Alchemilla glaucescens Wallr.	1	0.050180	-0.068984	0.217000	1.310000	0.763000	0.836000
BR0000010930052	Alchemilla glaucescens Wallr.	1	0.299300	-0.015265	0.183000	1.132000	0.883000	0.807000
BR0000010930083	Alchemilla glaucescens Wallr.	1	0.184356	-0.033288	0.188000	1.180000	0.847000	0.820000
BR0000010971529	Alchemilla glaucescens Wallr.	4	0.005280	-0.030758	0.238250	1.340000	0.748750	0.817750
BR0000011093244	Alchemilla glaucescens Wallr.	1	0.143097	0.004519	0.184000	1.182000	0.846000	0.829000
BR0000011093411	Alchemilla monticola Opiz	2	0.140950	0.007781	0.265000	1.180000	0.849000	0.845000
BR0000011093558	Alchemilla glabra Neygenf.	3	0.006791	0.024674	0.264000	1.297667	0.773333	0.790333
BR0000011093770	Alchemilla monticola Opiz	2	0.038362	-0.000728	0.129000	1.277000	0.784500	0.641000
BR0000011093886	Alchemilla glabra Neygenf.	2	0.101598	0.017434	0.304500	1.266500	0.790000	0.798500
BR0000011094104	Alchemilla monticola Opiz	1	0.162404	-0.068910	0.350000	1.214000	0.823000	0.875000
BR0000011094272	Alchemilla glaucescens Wallr.	2	0.043447	-0.010131	0.222000	1.293500	0.773500	0.829000
BR0000011094302	Alchemilla glaucescens Wallr.	2	0.125780	0.065055	0.207000	1.168500	0.856000	0.841000
BR0000011094395	Alchemilla glaucescens Wallr.	1	0.042524	0.058043	0.196000	1.165000	0.858000	0.821000
BR0000011094579	Alchemilla glaucescens Wallr.	1	0.013370	-0.000425	0.222000	1.490000	0.671000	0.834000
BR0000011094630	Alchemilla glaucescens Wallr.	1	0.044586	0.030798	0.205000	1.210000	0.826000	0.795000
BR0000011094722	Alchemilla glaucescens Wallr.	2	0.099813	0.067970	0.195500	1.227000	0.815500	0.805000
BR0000011094753	Alchemilla glaucescens Wallr.	2	0.002042	0.044319	0.261000	1.331000	0.752500	0.853000
BR0000011094784	Alchemilla monticola Opiz	1	-0.005129	-0.009387	0.327000	1.300000	0.769000	0.825000
BR0000011094845	Alchemilla glabra Neygenf.	1	-0.048858	-0.018523	0.295000	1.331000	0.751000	0.772000
BR0000011094937	Alchemilla glaucescens Wallr.	2	-0.059173	0.055925	0.255500	1.411000	0.713000	0.845500
BR0000011094968	Alchemilla glaucescens Wallr.	1	0.202522	-0.045136	0.228000	1.249000	0.801000	0.823000
BR0000011095088	Alchemilla monticola Opiz	2	-0.009360	0.031004	0.344000	1.290000	0.777000	0.856500
BR0000011095118	Alchemilla monticola Opiz	1	-0.081646	-0.028555	0.331000	1.343000	0.745000	0.834000
BR0000011095170	Alchemilla glabra Neygenf.	1	-0.010858	-0.073243	0.275000	1.316000	0.760000	0.822000
BR0000011095378	Alchemilla monticola Opiz	1	0.100328	-0.006415	0.015000	1.272000	0.786000	0.497000
BR0000011095385	Alchemilla glaucescens Wallr.	1	0.052487	0.044364	0.199000	1.172000	0.853000	0.817000
BR0000011095415	Alchemilla glaucescens Wallr.	3	0.128060	0.043777	0.254000	1.190333	0.841000	0.833667
BR0000011095644	Alchemilla monticola Opiz	1	0.068911	0.031668	0.288000	1.263000	0.792000	0.846000
BR0000011095910	Alchemilla monticola Opiz	5	0.060859	0.028483	0.285800	1.235800	0.810400	0.844000
BR0000011095972	Alchemilla monticola Opiz	3	0.065733	0.044966	0.289333	1.196667	0.837333	0.839667
BR0000011096061	Alchemilla monticola Opiz	1	0.089164	-0.017448	0.268000	1.229000	0.814000	0.783000
BR0000011096153	Alchemilla glaucescens Wallr.	2	0.030985	0.070113	0.237500	1.235500	0.809500	0.812500
BR0000011158059	Alchemilla glabra Neygenf.	1	-0.138523	0.007663	0.264000	1.433000	0.698000	0.818000
BR0000012123278	Alchemilla glabra Neygenf.	1	-0.158109	-0.039624	0.008000	1.432000	0.698000	0.492000
BR0000012123377	Alchemilla glabra Neygenf.	1	-0.079139	-0.026701	0.279000	1.481000	0.675000	0.781000
BR0000012291076	Alchemilla glaucescens Wallr.	3	0.094649	0.024013	0.290000	1.289000	0.776333	0.839000
BR0000012311989	Alchemilla monticola Opiz	1	-0.039077	-0.061031	0.343000	1.402000	0.714000	0.864000
BR0000012312023	Alchemilla monticola Opiz	1	-0.089400	0.054217	0.303000	1.371000	0.729000	0.818000
BR0000012312047	Alchemilla monticola Opiz	3	0.105741	-0.012424	0.349667	1.215000	0.823667	0.850000
BR0000012312061	Alchemilla monticola Opiz	2	0.151501	-0.035194	0.228500	1.151000	0.870000	0.841000
BR0000012312115	Alchemilla glabra Neygenf.	1	-0.127010	0.024437	0.358000	1.405000	0.712000	0.839000
BR0000012312122	Alchemilla glabra Neygenf.	1	-0.117380	0.043784	0.293000	1.442000	0.693000	0.801000
BR0000012312139	Alchemilla glabra Neygenf.	2	-0.037697	0.000558	0.302500	1.330000	0.751500	0.781500
BR0000012312153	Alchemilla glabra Neygenf.	2	-0.104795	0.012409	0.299000	1.372500	0.728500	0.808500
BR0000012359721	Alchemilla glabra Neygenf.	1	-0.024142	0.018320	0.313000	1.268000	0.789000	0.846000
BR0000012444038	Alchemilla glaucescens Wallr.	1	0.143980	-0.150996	0.281000	1.182000	0.846000	0.787000
BR0000012594511	Alchemilla glaucescens Wallr.	1	0.187350	-0.016546	0.256000	1.238000	0.808000	0.853000
BR0000012594818	Alchemilla monticola Opiz	1	0.060067	-0.128607	0.347000	1.274000	0.785000	0.808000
BR0000012595082	Alchemilla glabra Neygenf.	2	-0.067844	-0.086540	0.229000	1.376500	0.729000	0.767000
BR0000012595181	Alchemilla glabra Neygenf.	2	-0.109220	0.028706	0.265500	1.415500	0.712000	0.800500
BR0000012595389	Alchemilla glabra Neygenf.	1	-0.008462	-0.009774	0.384000	1.434000	0.697000	0.858000
BR0000012595488	Alchemilla glaucescens Wallr.	1	0.247721	0.022188	0.285000	1.208000	0.827000	0.871000
BR0000012595655	Alchemilla glabra Neygenf.	2	0.069868	-0.021478	0.247000	1.270500	0.787500	0.783500

BR0000012595754	Alchemilla glabra Neygenf.	1	-0.018098	-0.079083	0.318000	1.330000	0.752000	0.790000
BR0000022438560	Alchemilla monticola Opiz	1	-0.011146	0.057244	0.251000	1.224000	0.817000	0.860000
BR0000024647526	Alchemilla glabra Neygenf.	1	-0.142382	0.015993	0.281000	1.385000	0.722000	0.758000
BR0000024647564	Alchemilla monticola Opiz	1	0.067806	-0.006369	0.304000	1.279000	0.782000	0.814000
BR0000025301946V	Alchemilla monticola Opiz	3	0.058278	0.011621	0.258667	1.246667	0.808000	0.806333
BR0000025301977V	Alchemilla monticola Opiz	1	0.030899	0.028785	0.227000	1.245000	0.803000	0.815000
BR0000025301991V	Alchemilla monticola Opiz	1	-0.055369	-0.076689	0.205000	1.302000	0.768000	0.736000
BR0000025302011V	Alchemilla monticola Opiz	1	0.045194	0.053577	0.225000	1.167000	0.857000	0.778000
BR0000025302028V	Alchemilla monticola Opiz	2	0.037944	0.019766	0.331500	1.293500	0.779000	0.841500
BR0000025302042V	Alchemilla monticola Opiz	3	0.049493	-0.002088	0.258333	1.254000	0.797667	0.789667
BR0000025302059V	Alchemilla monticola Opiz	2	0.022070	0.061108	0.270500	1.227500	0.823000	0.817000
BR0000025302066V	Alchemilla monticola Opiz	1	0.075863	0.005217	0.345000	1.264000	0.791000	0.854000
BR0000025302110V	Alchemilla monticola Opiz	2	-0.048623	-0.014147	0.262500	1.318000	0.759500	0.786000
BR0000025302288V	Alchemilla glaucescens Wallr.	1	-0.100877	-0.058356	0.249000	1.484000	0.674000	0.815000
BR0000025302295V	Alchemilla glaucescens Wallr.	1	-0.030595	0.032668	0.296000	1.294000	0.773000	0.830000
BR0000025302332V	Alchemilla glaucescens Wallr.	2	0.183047	0.007676	0.220500	1.236000	0.810500	0.812500
BR0000025635553V	Alchemilla glabra Neygenf.	1	0.115989	-0.104012	0.334000	1.273000	0.785000	0.792000
BR0000026172668V	Alchemilla glabra Neygenf.	2	-0.089184	-0.003707	0.306000	1.430500	0.699500	0.779500
BR0000026172682V	Alchemilla glaucescens Wallr.	1	0.059477	-0.045683	0.159000	1.302000	0.768000	0.813000
BR0000026172712V	Alchemilla monticola Opiz	2	0.062590	0.036428	0.137500	2.219000	0.560000	0.662000
BR0000026271798V	Alchemilla glabra Neygenf.	2	0.050757	-0.011621	0.288500	1.323500	0.756500	0.823500
BR0000026273174V	Alchemilla glabra Neygenf.	1	0.009769	0.059515	0.260000	1.274000	0.785000	0.803000
BR0000027433041V	Alchemilla glabra Neygenf.	1	-0.045541	0.038581	0.286000	1.358000	0.737000	0.797000
BR0000027433065V	Alchemilla glabra Neygenf.	2	-0.105124	-0.090939	0.294500	1.469000	0.681000	0.833500
BR0000027433072V	Alchemilla glabra Neygenf.	1	-0.199137	-0.024736	0.327000	1.606000	0.623000	0.854000
BR0000027433089V	Alchemilla glabra Neygenf.	1	0.027478	0.062087	0.367000	1.257000	0.796000	0.840000
BR0000027433096V	Alchemilla glabra Neygenf.	1	-0.154231	-0.071173	0.297000	1.447000	0.691000	0.859000
BR0000027464106V	Alchemilla monticola Opiz	2	-0.044689	0.014331	0.248500	1.341000	0.748000	0.796000
BR0000027739303V	Alchemilla glabra Neygenf.	1	-0.061976	0.064067	0.014000	1.203000	0.831000	0.532000
BR0000031845236	Alchemilla monticola Opiz	3	0.023091	-0.003702	0.285000	1.417000	0.714333	0.807000
BR0000031845250	Alchemilla monticola Opiz	2	0.038229	0.039714	0.257000	1.273000	0.790500	0.825500
BR0000031845267	Alchemilla monticola Opiz	3	-0.056626	0.041173	0.332667	1.377667	0.728333	0.793667
BR0000031845274	Alchemilla monticola Opiz	2	0.087310	0.026057	0.335500	1.235000	0.817500	0.839500
BR0000031845328	Alchemilla monticola Opiz	1	0.206597	0.048323	0.245000	1.162000	0.861000	0.853000
BR0000031845458	Alchemilla monticola Opiz	3	-0.122892	-0.031473	0.366333	1.399667	0.715000	0.833333
BR0000031845526	Alchemilla monticola Opiz	2	0.051633	-0.053403	0.273500	1.316500	0.760000	0.796500
BR0000031845533	Alchemilla monticola Opiz	2	0.034949	0.084166	0.211000	1.214000	0.824000	0.793500
BR0000031845540	Alchemilla monticola Opiz	1	0.014478	-0.059478	0.451000	1.409000	0.710000	0.857000
BR0000036322763	Alchemilla glabra Neygenf.	1	-0.034068	0.035189	0.304000	1.246000	0.803000	0.829000
E00093039	Alchemilla glaucescens Wallr.	1	0.044995	-0.026498	0.020000	1.462000	0.684000	0.479000
E00093043	Alchemilla monticola Opiz	1	0.042816	-0.049808	0.291000	1.267000	0.789000	0.793000
E00128233	Alchemilla monticola Opiz	1	0.076976	-0.049234	0.219000	1.253000	0.798000	0.816000
E00128235	Alchemilla subcrenata Buser	1	-0.024874	-0.030327	0.317000	1.302000	0.768000	0.773000
E00128241	Alchemilla glabra Neygenf.	3	0.007955	0.021007	0.260333	1.352000	0.742000	0.670667
E00441087	Alchemilla mollis (Buser) Rothm.	1	-0.167312	-0.055060	0.286000	1.319000	0.758000	0.834000
E00441088	Alchemilla mollis (Buser) Rothm.	1	0.189456	-0.002255	0.284000	1.131000	0.884000	0.893000
E00441092	Alchemilla mollis (Buser) Rothm.	1	-0.119373	0.057900	0.325000	1.320000	0.757000	0.840000
E00639970	Alchemilla glaucescens Wallr.	1	0.130915	0.004737	0.301000	1.260000	0.794000	0.844000
E00678057	Alchemilla glabra Neygenf.	1	-0.005540	-0.066574	0.277000	1.351000	0.740000	0.829000
E00678066	Alchemilla glaucescens Wallr.	1	0.049776	0.069309	0.048000	1.233000	0.811000	0.364000
E00678067	Alchemilla glaucescens Wallr.	1	0.030123	-0.010326	0.159000	2.921000	0.342000	0.424000
E00678068	Alchemilla glaucescens Wallr.	1	-0.042191	-0.004845	0.018000	1.785000	0.560000	0.400000
E00678069	Alchemilla glaucescens Wallr.	1	0.154674	0.015956	0.281000	1.023000	0.977000	0.844000
E00678070	Alchemilla glaucescens Wallr.	1	0.129136	0.063910	0.310000	1.206000	0.829000	0.825000
E00678071	Alchemilla glaucescens Wallr.	2	0.073815	-0.013125	0.288500	1.284000	0.779000	0.837000
E00678074	Alchemilla glaucescens Wallr.	1	0.113123	0.008692	0.341000	1.239000	0.807000	0.861000
E00678083	Alchemilla mollis (Buser) Rothm.	1	-0.032289	-0.012756	0.319000	1.284000	0.779000	0.867000
E00800254	Alchemilla subcrenata Buser	2	0.169398	-0.031531	0.308000	1.205000	0.832000	0.833500
E00800447	Alchemilla glabra Neygenf.	1	-0.181503	0.019325	0.351000	1.435000	0.697000	0.826000
E00800451	Alchemilla glabra Neygenf.	1	-0.064477	0.028830	0.291000	1.341000	0.746000	0.784000
E00800452	Alchemilla glabra Neygenf.	1	0.005595	-0.019568	0.317000	1.362000	0.734000	0.842000
E00800453	Alchemilla glabra Neygenf.	2	-0.030797	-0.066084	0.312500	1.391000	0.719000	0.831000
E00800454	Alchemilla glabra Neygenf.	1	-0.171123	0.007862	0.234000	1.501000	0.666000	0.773000
E00800456	Alchemilla glabra Neygenf.	1	-0.188635	-0.006683	0.268000	1.405000	0.712000	0.840000
E00800459	Alchemilla glabra Neygenf.	1	0.057371	0.036972	0.059000	1.170000	0.855000	0.333000
E00800464	Alchemilla glabra Neygenf.	2	0.020210	0.001946	0.208500	1.228500	0.814500	0.671500
E00800465	Alchemilla glabra Neygenf.	1	-0.028297	0.070682	0.261000	1.272000	0.786000	0.857000
E00800466	Alchemilla glabra Neygenf.	2	-0.135365	0.038741	0.290000	1.502500	0.666000	0.796000
E00800467	Alchemilla glabra Neygenf.	1	-0.065224	0.049479	0.272000	1.251000	0.800000	0.829000
E00800469	Alchemilla glabra Neygenf.	1	-0.045040	0.047490	0.006000	1.343000	0.745000	0.392000
E00800475	Alchemilla glabra Neygenf.	1	0.009084	0.049990	0.230000	1.180000	0.847000	0.785000
E00800480	Alchemilla glabra Neygenf.	3	-0.093125	0.001149	0.263333	1.382333	0.723667	0.796667
E00800481	Alchemilla glabra Neygenf.	1	0.127910	0.089227	0.196000	1.225000	0.816000	0.879000
E00800482	Alchemilla glabra Neygenf.	1	-0.004962	-0.102038	0.155000	1.273000	0.786000	0.790000
E00800485	Alchemilla glabra Neygenf.	1	0.016938	-0.029553	0.287000	1.319000	0.758000	0.778000
E00800486	Alchemilla glabra Neygenf.	1	0.058440	-0.058713	0.276000	1.265000	0.791000	0.823000
E00800487	Alchemilla glabra Neygenf.	1	0.071927	-0.058368	0.004000	1.817000	0.550000	0.301000
E00800491	Alchemilla glabra Neygenf.	1	0.031527	0.024853	0.066000	1.170000	0.855000	0.377000
E00800494	Alchemilla glabra Neygenf.	1	-0.033014	-0.081052	0.009000	1.227000	0.815000	0.398000
E00800495	Alchemilla glabra Neygenf.	1	0.287081	-0.132701	0.330000	1.132000	0.883000	0.855000
E00800496	Alchemilla glabra Neygenf.	3	-0.039903	0.009844	0.315000	1.324333	0.755333	0.787667
E00800497	Alchemilla glabra Neygenf.	1	-0.055209	-0.011085	0.312000	1.305000	0.767000	0.779000
E00800498	Alchemilla glabra Neygenf.	1	-0.042176	0.030077	0.255000	1.135000	0.881000	0.328000
E00829018	Alchemilla glabra Neygenf.	1	0.120731	-0.082227	0.236000	1.338000	0.747000	0.760000
E00829023	Alchemilla glabra Neygenf.	1	-0.114005	-0.042024	0.249000	1.411000	0.709000	0.801000
E00829033	Alchemilla glabra Neygenf.	1	0.108407	-0.037223	0.060000	1.138000	0.878000	0.354000
E00829034	Alchemilla glabra Neygenf.	1	0.025791	0.103261	0.307000	1.175000	0.851000	0.863000
E00829035	Alchemilla glabra Neygenf.	1	0.015717	0.037281	0.364000	1.246000	0.803000	0.845000
E00829036	Alchemilla glabra Neygenf.	1	-0.141813	-0.025805	0.052000	1.270000	0.787000	0.332000
E00829043	Alchemilla glabra Neygenf.	1	-0.019238	0.095807	0.213000	1.237000	0.808000	0.815000
E00829045	Alchemilla glabra Neygenf.	1	0.009229	-0.060018	0.417000	1.397000	0.716000	0.836000
E00829046	Alchemilla glabra Neygenf.	1	0.050691	0.017485	0.303000	1.289000	0.776000	0.753000
E00829051	Alchemilla glabra Neygenf.	1	-0.146619	-0.027892	0.009000	1.803000	0.555000	0.392000
E00829052	Alchemilla glabra Neygenf.	2	-0.070717	-0.077716	0.332500	1.513500	0.663500	0.831500

E00829053	Alchemilla glabra Neygenf.	1	-0.081789	-0.021296	0.228000	1.361000	0.735000	0.792000
E00829055	Alchemilla glabra Neygenf.	1	0.092010	0.002510	0.074000	1.185000	0.844000	0.410000
E00829057	Alchemilla glabra Neygenf.	1	-0.255472	-0.074844	0.301000	1.587000	0.630000	0.875000
E00829060	Alchemilla glabra Neygenf.	1	-0.118398	-0.068020	0.023000	1.581000	0.632000	0.515000
E00829067	Alchemilla glabra Neygenf.	1	-0.091055	0.051654	0.325000	1.286000	0.778000	0.844000
E00829068	Alchemilla glabra Neygenf.	1	-0.040234	-0.020332	0.247000	1.261000	0.793000	0.753000
E00829070	Alchemilla glabra Neygenf.	1	-0.049442	-0.063445	0.247000	1.144000	0.874000	0.845000
E00829071	Alchemilla glabra Neygenf.	1	0.033338	-0.011190	0.006000	1.716000	0.583000	0.401000
E00829073	Alchemilla glabra Neygenf.	3	0.019581	0.043754	0.322000	1.265000	0.791000	0.835333
E00829074	Alchemilla glabra Neygenf.	1	-0.032557	0.010624	0.053000	1.254000	0.797000	0.457000
E00829076	Alchemilla glabra Neygenf.	2	-0.025570	0.035295	0.244000	1.276500	0.793000	0.605000
E00829078	Alchemilla glabra Neygenf.	1	-0.093770	-0.031871	0.015000	1.714000	0.584000	0.458000
E00829079	Alchemilla glabra Neygenf.	2	-0.118361	-0.024370	0.252500	1.352000	0.741500	0.606000
E00829080	Alchemilla glabra Neygenf.	1	0.083746	-0.089570	0.308000	1.482000	0.675000	0.820000
E00829083	Alchemilla glabra Neygenf.	1	0.129123	-0.040369	0.310000	1.181000	0.846000	0.833000
E00829084	Alchemilla glabra Neygenf.	1	-0.167047	0.007648	0.256000	1.432000	0.698000	0.761000
E00829085	Alchemilla glabra Neygenf.	1	-0.058887	0.020690	0.008000	1.401000	0.714000	0.410000
E00829086	Alchemilla glabra Neygenf.	1	-0.045589	0.045632	0.369000	1.286000	0.778000	0.833000
E00829088	Alchemilla glabra Neygenf.	2	0.046438	-0.041137	0.287500	1.356000	0.738000	0.837500
E00829092	Alchemilla glabra Neygenf.	8	0.021519	-0.025297	0.342750	1.310750	0.765250	0.782500
E00829093	Alchemilla glabra Neygenf.	5	-0.037038	0.037503	0.350400	1.302600	0.769800	0.811200
E00829094	Alchemilla glabra Neygenf.	1	-0.066530	-0.036324	0.333000	1.295000	0.772000	0.787000
E00829095	Alchemilla glabra Neygenf.	1	-0.089911	-0.097339	0.281000	1.138000	0.878000	0.361000
E00829096	Alchemilla glabra Neygenf.	1	-0.110471	-0.036052	0.012000	1.288000	0.776000	0.389000
E00829098	Alchemilla glabra Neygenf.	1	0.053544	-0.082003	0.348000	1.278000	0.782000	0.849000
E00829099	Alchemilla glabra Neygenf.	1	-0.027768	-0.027151	0.302000	1.441000	0.694000	0.861000
E00829103	Alchemilla mollis (Buser) Rothm.	1	0.054168	0.060123	0.340000	1.332000	0.751000	0.885000
E00829104	Alchemilla mollis (Buser) Rothm.	1	-0.082175	-0.062386	0.242000	1.186000	0.843000	0.314000
E00829105	Alchemilla mollis (Buser) Rothm.	1	0.090498	0.049435	0.226000	1.134000	0.882000	0.289000
E00829106	Alchemilla mollis (Buser) Rothm.	1	0.058782	0.047380	0.383000	1.125000	0.889000	0.490000
E00829107	Alchemilla mollis (Buser) Rothm.	4	0.033277	0.018159	0.390500	1.218000	0.822500	0.900750
E00829109	Alchemilla mollis (Buser) Rothm.	1	-0.205680	-0.016675	0.363000	1.482000	0.675000	0.883000
E01153123	Alchemilla glabra Neygenf.	1	-0.146723	-0.098380	0.455000	1.519000	0.658000	0.888000
E01153124	Alchemilla glabra Neygenf.	2	-0.067891	-0.036708	0.019000	1.590000	0.629500	0.388000
E01153126	Alchemilla glabra Neygenf.	1	-0.129545	-0.024203	0.215000	1.451000	0.689000	0.769000
E01153127	Alchemilla glabra Neygenf.	1	0.023159	0.034059	0.017000	1.367000	0.732000	0.572000
E01153128	Alchemilla glabra Neygenf.	1	0.061401	-0.065957	0.359000	1.377000	0.726000	0.843000
E01153131	Alchemilla glabra Neygenf.	2	-0.017812	0.038974	0.318000	1.241000	0.809500	0.563000
E01153133	Alchemilla glabra Neygenf.	1	0.020181	0.018134	0.436000	1.377000	0.726000	0.849000
E01153135	Alchemilla glabra Neygenf.	1	-0.073165	0.049236	0.307000	1.341000	0.745000	0.804000
E01153145	Alchemilla glaucescens Wallr.	1	0.037589	0.060160	0.017000	1.230000	0.813000	0.353000
E01153147	Alchemilla glaucescens Wallr.	1	0.004463	-0.010285	0.010000	1.922000	0.520000	0.327000
E01153149	Alchemilla glaucescens Wallr.	1	-0.054755	0.003081	0.222000	1.282000	0.780000	0.858000
E01153151	Alchemilla glaucescens Wallr.	1	0.165994	-0.072747	0.290000	1.201000	0.833000	0.840000
E01153152	Alchemilla glaucescens Wallr.	1	0.104710	0.098848	0.291000	1.193000	0.838000	0.840000
E01153153	Alchemilla glaucescens Wallr.	2	0.130840	0.012021	0.161000	1.420000	0.734000	0.683500
E01153170	Alchemilla propinqua H.Lindb. ex Juz.	1	0.015654	0.062565	0.224000	1.249000	0.800000	0.820000
E01153213	Alchemilla monticola Opiz	1	0.083468	-0.042834	0.303000	1.274000	0.785000	0.856000
E01153214	Alchemilla monticola Opiz	2	0.011404	-0.019049	0.200500	1.700000	0.591500	0.656000
E01153215	Alchemilla monticola Opiz	2	0.030596	-0.029875	0.006500	1.608500	0.643000	0.389500
E01153216	Alchemilla monticola Opiz	1	0.078832	-0.008843	0.272000	1.226000	0.816000	0.823000
E01153218	Alchemilla glaucescens Wallr.	1	0.090856	-0.019438	0.267000	1.224000	0.817000	0.823000
E01153219	Alchemilla monticola Opiz	1	-0.069330	0.023268	0.308000	1.276000	0.784000	0.804000
E01153220	Alchemilla monticola Opiz	1	0.183044	-0.041998	0.320000	1.166000	0.858000	0.832000
E01153221	Alchemilla monticola Opiz	1	0.086477	-0.078979	0.262000	1.219000	0.821000	0.858000
E01153222	Alchemilla monticola Opiz	1	0.250015	-0.091364	0.291000	1.214000	0.823000	0.840000
E01153223	Alchemilla monticola Opiz	1	0.056221	-0.109524	0.422000	1.332000	0.751000	0.850000
E01153224	Alchemilla monticola Opiz	1	-0.053047	-0.017519	0.055000	1.112000	0.899000	0.357000
E01153225	Alchemilla monticola Opiz	1	-0.037878	0.031275	0.303000	1.104000	0.906000	0.387000
E01153228	Alchemilla monticola Opiz	2	0.078861	0.054895	0.162000	2.085500	0.564000	0.596500
E01153229	Alchemilla monticola Opiz	2	-0.004629	-0.089900	0.229500	1.770000	0.587000	0.565500
E01153232	Alchemilla monticola Opiz	2	-0.009729	-0.025737	0.200000	1.264500	0.791500	0.794000
E01153251	Alchemilla mollis (Buser) Rothm.	1	-0.072041	-0.076187	0.371000	1.408000	0.710000	0.879000
E01153299	Alchemilla monticola Opiz	1	0.024067	-0.004263	0.012000	1.228000	0.814000	0.459000
E01153312	Alchemilla glaucescens Wallr.	2	0.102552	-0.089979	0.202000	1.404000	0.714500	0.707000
E01153327	Alchemilla subcrenata Buser	1	0.168512	0.081153	0.297000	1.134000	0.882000	0.378000
E01153328	Alchemilla subcrenata Buser	1	0.043863	0.009153	0.257000	1.276000	0.784000	0.798000
E01153329	Alchemilla subcrenata Buser	1	-0.001210	0.172246	0.368000	1.242000	0.805000	0.886000
E01153330	Alchemilla subcrenata Buser	1	0.164884	-0.058246	0.250000	1.269000	0.788000	0.820000
E01153333	Alchemilla subcrenata Buser	1	0.046464	0.148546	0.004000	1.347000	0.743000	0.417000
E01153335	Alchemilla subcrenata Buser	3	0.079771	-0.066297	0.374333	1.330000	0.755000	0.814667
E01153336	Alchemilla subcrenata Buser	1	0.076156	-0.091417	0.242000	1.297000	0.771000	0.775000
K000914197	Alchemilla mollis (Buser) Rothm.	2	0.124295	-0.009445	0.468500	1.235500	0.809500	0.898000
KRAM 62190	Alchemilla glaucescens Wallr.	1	-0.092961	-0.063354	0.351000	1.145000	0.873000	0.869000
KRAM00028870-V	Alchemilla glaucescens Wallr.	1	-0.094532	0.046892	0.026000	2.736000	0.366000	0.487000
KRAM00028872-V	Alchemilla glaucescens Wallr.	3	0.121643	-0.029873	0.261333	1.240667	0.808000	0.667000
KRAM00028878-V	Alchemilla glaucescens Wallr.	1	0.057727	0.256530	0.431000	1.183000	0.845000	0.847000
KRAM00028880-V	Alchemilla glaucescens Wallr.	1	-0.018550	0.106432	0.324000	1.212000	0.825000	0.791000
KRAM304648	Alchemilla glabra Neygenf.	1	-0.054310	-0.014335	0.311000	1.337000	0.748000	0.777000
KRAM323223	Alchemilla glaucescens Wallr.	3	0.000248	0.006530	0.198667	1.357667	0.738333	0.711000
KRAM323233	Alchemilla glaucescens Wallr.	1	0.048123	-0.020636	0.220000	1.226000	0.816000	0.821000
KRAM323240	Alchemilla glaucescens Wallr.	1	0.021070	0.020076	0.234000	1.282000	0.780000	0.817000
KRAM323266	Alchemilla glabra Neygenf.	1	0.083781	-0.019478	0.305000	1.246000	0.802000	0.848000
KRAM323272	Alchemilla glabra Neygenf.	1	-0.178754	-0.034776	0.301000	1.383000	0.723000	0.813000
KRAM323273	Alchemilla glabra Neygenf.	4	-0.117324	-0.029761	0.337750	1.436000	0.699750	0.816500
KRAM323275	Alchemilla glabra Neygenf.	1	0.105803	0.024520	0.231000	1.148000	0.871000	0.793000
KRAM323448	Alchemilla glabra Neygenf.	1	0.007243	-0.093146	0.372000	1.518000	0.659000	0.797000
KRAM323449	Alchemilla glabra Neygenf.	1	0.042628	-0.040986	0.002000	1.447000	0.691000	0.232000
KRAM323452	Alchemilla glabra Neygenf.	1	0.011777	0.001444	0.423000	1.387000	0.721000	0.823000
KRAM323458	Alchemilla glabra Neygenf.	4	0.100555	-0.013843	0.376250	1.292000	0.778000	0.828500
KRAM323466	Alchemilla glabra Neygenf.	2	-0.002329	-0.049878	0.315500	1.349500	0.741000	0.834000
KRAM323476	Alchemilla glabra Neygenf.	2	-0.029087	-0.003254	0.466000	1.396500	0.716500	0.817500
KRAM323480	Alchemilla glabra Neygenf.	1	0.157347	-0.080356	0.360000	1.240000	0.807000	0.854000
KRAM328232	Alchemilla glaucescens Wallr.	2	0.090534	-0.029093	0.234000	1.223000	0.822000	0.590000

KRAM329440	Alchemilla glabra Neygenf.	1	-0.216181	-0.039495	0.300000	1.554000	0.643000	0.826000
KRAM329446	Alchemilla glabra Neygenf.	1	-0.044958	-0.023332	0.438000	1.315000	0.760000	0.784000
KRAM329448	Alchemilla glabra Neygenf.	1	-0.156393	0.026020	0.346000	1.435000	0.697000	0.848000
KRAM397299	Alchemilla glabra Neygenf.	1	-0.106794	0.022095	0.333000	1.456000	0.687000	0.798000
UGDA.0023974	Alchemilla monticola Opiz	2	0.028869	0.029399	0.214500	1.208500	0.828000	0.813000
UGDA.0023982	Alchemilla monticola Opiz	1	0.110630	-0.058353	0.231000	1.201000	0.833000	0.792000
UGDA.0031237	Alchemilla sp.	1	0.039614	-0.008397	0.359000	1.253000	0.798000	0.801000
UGDA.0033311	Alchemilla monticola Opiz	1	-0.118331	0.053655	0.082000	1.395000	0.717000	0.764000
UGDA.0033737	Alchemilla pastoralis Buser	3	0.010509	-0.010700	0.274333	1.252000	0.799333	0.822000
UGDA.0040839	Alchemilla pastoralis Buser	2	-0.022999	0.061038	0.204000	1.284000	0.783000	0.792500
UGDA.0040842	Alchemilla glabra Neygenf.	2	-0.029501	0.000804	0.320500	1.382500	0.723500	0.815500
UGDA.0040925	Alchemilla monticola Opiz	1	0.052717	0.059942	0.293000	1.252000	0.799000	0.858000
UGDA.0040926	Alchemilla obtusa Buser	1	0.002829	0.108420	0.322000	1.310000	0.763000	0.825000
UGDA.0040927	Alchemilla monticola Opiz	2	-0.056483	0.071238	0.292500	1.274000	0.785000	0.801000
UGDA.0064213	Alchemilla sp.	2	-0.029098	-0.035352	0.258000	1.393000	0.717500	0.838000
UGDA.0087204	Alchemilla sp.	1	-0.125536	-0.045555	0.292000	1.474000	0.679000	0.869000
UGDA.0093434	Alchemilla monticola Opiz	1	0.124464	0.031297	0.310000	1.223000	0.818000	0.810000
UGDA.0093435	Alchemilla monticola Opiz	2	0.106997	-0.034839	0.158000	1.243500	0.805000	0.700000
UGDA.0097304	Alchemilla sp.	1	-0.045230	-0.040613	0.278000	1.340000	0.746000	0.801000
UGDA.0098982	Alchemilla sp.	1	0.064832	-0.108171	0.242000	1.229000	0.814000	0.786000
UGDA.0098985	Alchemilla sp.	1	0.125039	0.081543	0.335000	1.248000	0.801000	0.843000
UGDA.0099046	Alchemilla vulgaris L.	1	0.052187	-0.003897	0.301000	1.259000	0.794000	0.830000
UGDA.0109002	Alchemilla sp.	1	0.067716	0.012635	0.306000	1.287000	0.777000	0.845000
UGDA.0109005	Alchemilla sp.	1	0.067712	-0.112044	0.041000	2.695000	0.371000	0.371000
UGDA.0109016	Alchemilla sp.	1	-0.032648	0.072016	0.329000	1.172000	0.853000	0.880000
UGDA.0109019	Alchemilla sp.	1	0.019921	0.073614	0.348000	1.266000	0.790000	0.858000
UGDA.0114795	Alchemilla sp.	1	-0.007882	0.057790	0.404000	1.397000	0.716000	0.815000
UGDA.0114796	Alchemilla monticola Opiz	2	0.141997	-0.004393	0.283000	1.217000	0.822000	0.862000
UGDA.0114797	Alchemilla sp.	1	0.102766	-0.033804	0.254000	1.251000	0.799000	0.862000
UGDA.0114798	Alchemilla acutiloba Opiz	1	0.013211	0.076405	0.363000	1.433000	0.698000	0.782000
UGDA.0114801	Alchemilla sp.	1	-0.060654	0.015778	0.320000	1.344000	0.744000	0.847000
UGDA.0114802	Alchemilla sp.	1	-0.043127	0.061165	0.366000	1.403000	0.713000	0.827000
UGDA.0114823	Alchemilla sp.	2	-0.009270	-0.015097	0.340000	1.344500	0.745000	0.815500
UGDA.0114824	Alchemilla sp.	1	-0.017471	0.076759	0.299000	1.360000	0.735000	0.843000
UGDA.0114826	Alchemilla sp.	1	0.093448	-0.107753	0.186000	1.143000	0.875000	0.806000
UGDA.0114913	Alchemilla sp.	2	0.048795	0.015346	0.317000	1.286500	0.780500	0.828500
UGDA.0128572	Alchemilla vulgaris L.	1	-0.053718	0.073250	0.073000	1.181000	0.847000	0.406000
UGDA.0137789	Alchemilla hybrida (L.) L.	2	-0.067066	-0.063590	0.350500	1.471500	0.685500	0.837000
UGDA.0139632	Alchemilla vulgaris L.	1	-0.000923	0.040622	0.346000	1.124000	0.890000	0.441000
UGDA.0140624	Alchemilla monticola Opiz	2	0.039957	0.005349	0.335500	1.338500	0.751000	0.823500
UGDA.0141940	Alchemilla sp.	1	-0.146216	0.032200	0.438000	1.416000	0.706000	0.851000
UGDA.0142522	Alchemilla propinqua H.Lindb. ex Juz.	1	0.048390	0.066372	0.061000	1.101000	0.908000	0.379000
UGDA.0142862	Alchemilla acutiloba Opiz	1	0.038516	-0.018137	0.317000	1.271000	0.787000	0.776000
UGDA.0143251	Alchemilla pastoralis Buser	1	-0.091887	0.033198	0.278000	1.366000	0.732000	0.797000
UGDA.0173451	Alchemilla sp.	1	0.025251	0.006127	0.219000	1.377000	0.726000	0.805000
UGDA.0180955	Alchemilla vulgaris L.	1	0.043913	0.060810	0.369000	1.228000	0.815000	0.844000
UGDA.0201600	Alchemilla pastoralis Buser	1	-0.091256	-0.046158	0.272000	1.280000	0.781000	0.804000
UGDA.0215379	Alchemilla sp.	1	-0.169198	-0.070486	0.249000	1.616000	0.619000	0.827000
UGDA.0237565	Alchemilla pastoralis Buser	1	-0.335365	-0.126314	0.173000	1.505000	0.664000	0.828000
UGDA.0237575	Alchemilla pastoralis Buser	2	0.107859	-0.033882	0.358000	1.299000	0.770000	0.853500
UGDA.0237583	Alchemilla pastoralis Buser	1	0.126229	-0.008222	0.271000	1.232000	0.812000	0.854000
UGDA.0237584	Alchemilla propinqua H.Lindb. ex Juz.	1	0.116876	-0.094177	0.373000	1.259000	0.795000	0.849000
UGDA.0240211	Alchemilla sp.	1	-0.136121	-0.123892	0.308000	1.442000	0.694000	0.826000
UGDA.0240217	Alchemilla sp.	1	-0.098444	0.070921	0.191000	1.304000	0.767000	0.779000

For specimens represented by more than one leaf, morphometric shape descriptors (Circularity, Aspect ratio, Roundness, and Solidity) were averaged at the specimen level. PCA was performed on specimen-level mean normalized EFD coefficients based on 20 harmonics.

B. Summary of effective principal components

PC	Eigenvalue	Proportion of variance (%)	Cumulative variance (%)
PC1	0.008572939	39.1125	39.1125
PC2	0.003247562	14.8164	53.9290
PC3	0.001534758	7.0021	60.9310
PC4	0.001191746	5.4371	66.3682
PC5	0.001028419	4.6920	71.0601
PC6	0.000932099	4.2525	75.3127
PC7	0.000738451	3.3691	78.6817
PC8	0.000697853	3.1838	81.8656
PC9	0.000396851	1.8106	83.6761
PC10	0.000373141	1.7024	85.3785
PC11	0.000323936	1.4779	86.8564
PC12	0.000300829	1.3725	88.2289

Supplementary Table S3. Leaf morphometric dataset used for NMDS and cluster analyses, including specimen identifiers, morphometric variables, principal component scores, cluster assignments, and NMDS coordinates.

Supplementary Table S3. Leaf morphometric dataset used for NMDS and cluster analyses, including specimen identifiers, morphometric variables, principal component scores, cluster assignments, and NMDS coordinates.												
No.	**Specimen number**	**Taxon**	**Species**	**PC1**	**PC2**	**Circularity**	**Aspect_Ratio**	**Roundness**	**Solidity**	**Cluster**	**NMDS1**	**NMDS2**
1	UGDA.0114798	Alchemilla acutiloba Opiz	A_acutiloba_1	0.01321122	0.07640528	0.363	1.433	0.698	0.782	1	-0.065768228058916	0.381132332930376
2	UGDA.0142862	Alchemilla acutiloba Opiz	A_acutiloba_2	0.03851630	-0.01813734	0.317	1.271	0.787	0.776	1	-0.410296525935204	-0.159190354741284
3	WAG.1561156	Alchemilla glabra Neygenf.	A_glabra_1	-0.04845609	0.02126218	0.332	1.355	0.738	0.799	1	0.001428421746645	-0.174770845142159
4	L.1889332	Alchemilla glabra Neygenf.	A_glabra_2	-0.01692791	0.17090590	0.273	1.221	0.819	0.760	1	-0.573100323581935	1.431376369204390
5	L.1889323	Alchemilla glabra Neygenf.	A_glabra_3	-0.00048302	0.04941568	0.397	1.339	0.747	0.843	1	-0.401588427489512	-0.106627978793408
6	L.1889318	Alchemilla glabra Neygenf.	A_glabra_4	-0.02128653	-0.06373705	0.324	1.365	0.733	0.818	1	-0.203417564148881	-0.626594239068320
7	L.1889317	Alchemilla glabra Neygenf.	A_glabra_5	-0.08519245	-0.00954367	0.385	1.448	0.691	0.794	1	0.132997080317915	-0.678118581836933
8	L.1889326	Alchemilla glabra Neygenf.	A_glabra_6	-0.03265435	-0.11080750	0.316	1.451	0.689	0.776	1	-0.062398187755081	-1.092949819786170
9	L.1889320	Alchemilla glabra Neygenf.	A_glabra_7	-0.04214239	-0.02192577	0.445	1.380	0.725	0.836	1	-0.267101837645259	-0.883017919085820
10	L.3260878	Alchemilla glabra Neygenf.	A_glabra_8	0.03435856	-0.03053701	0.357	1.245	0.803	0.799	1	-0.527266059546885	-0.319503353811183
11	L.3260066	Alchemilla glabra Neygenf.	A_glabra_9	-0.11994450	0.04820462	0.318	1.414	0.707	0.822	1	0.421091110389122	-0.254888197625720
12	L.3260145	Alchemilla glabra Neygenf.	A_glabra_10	-0.04462847	0.07602997	0.313	1.331	0.751	0.783	1	0.067446717158815	0.272406100558207
13	L.3260194	Alchemilla glabra Neygenf.	A_glabra_11	-0.05374577	-0.06993972	0.385	1.689	0.592	0.869	1	0.179993719173070	-1.428083906192380
14	L.3260013	Alchemilla glabra Neygenf.	A_glabra_12	-0.06110317	0.00686010	0.344	1.433	0.701	0.835	1	0.069844707258175	-0.420169758251251
15	L.3249939	Alchemilla glabra Neygenf.	A_glabra_13	-0.11456200	-0.00189585	0.305	1.422	0.703	0.771	1	0.332186467313701	-0.412505417646364
16	L.3260105	Alchemilla glabra Neygenf.	A_glabra_14	-0.11287440	-0.01673983	0.451	1.507	0.664	0.842	1	0.127473533406808	-1.214112953179960
17	L.3260021	Alchemilla glabra Neygenf.	A_glabra_15	0.03165261	-0.03960076	0.208	1.453	0.691	0.637	1	0.539361672074678	0.197444031133321
18	L.3260170	Alchemilla glabra Neygenf.	A_glabra_16	-0.17640830	0.00867862	0.285	1.483	0.677	0.807	1	0.657793008828437	-0.612340272348858
19	L.3260053	Alchemilla glabra Neygenf.	A_glabra_17	0.04035941	0.06779141	0.286	1.245	0.803	0.860	1	-0.459668089708502	0.395625567790869
20	L.3260177	Alchemilla glabra Neygenf.	A_glabra_18	0.06113509	-0.04743944	0.264	1.339	0.749	0.751	1	-0.454209951650102	-0.276705143592313
21	L.3260161	Alchemilla glabra Neygenf.	A_glabra_19	-0.03387849	0.01059502	0.388	1.263	0.791	0.815	1	-0.287887712671658	-0.343616124646012
22	L.3260094	Alchemilla glabra Neygenf.	A_glabra_20	-0.12283280	-0.04272190	0.009	1.292	0.774	0.497	2	1.707079054761270	0.834888777754200
23	L.3260204	Alchemilla glabra Neygenf.	A_glabra_21	0.04123467	0.02440122	0.020	1.328	0.753	0.503	2	1.002077117338270	1.338478889644870
24	L.3249961	Alchemilla glabra Neygenf.	A_glabra_22	-0.02239174	-0.04429822	0.333	1.372	0.729	0.776	1	-0.142099235074299	-0.500548332569386
25	L.3260030	Alchemilla glabra Neygenf.	A_glabra_23	-0.00785198	0.15463630	0.274	1.105	0.905	0.818	1	-0.785138398295492	1.306789624146010
26	L.3260168	Alchemilla glabra Neygenf.	A_glabra_24	0.06237545	0.04204853	0.286	1.265	0.790	0.801	1	-0.431028873806190	0.260165591948495
27	L.3260027	Alchemilla glabra Neygenf.	A_glabra_25	-0.04982349	-0.06414771	0.321	1.445	0.692	0.797	1	0.008665175741914	-0.725983011398618
28	L.3260104	Alchemilla glabra Neygenf.	A_glabra_26	-0.07039013	0.03861214	0.297	1.304	0.767	0.808	1	0.085769859125016	-0.008385574058191
29	L.3260069	Alchemilla glabra Neygenf.	A_glabra_27	-0.17328860	-0.00279004	0.356	1.474	0.678	0.833	1	0.496540746277573	-0.882961465834425
30	L.3249992	Alchemilla glabra Neygenf.	A_glabra_28	0.02014068	0.12809290	0.300	1.231	0.813	0.836	1	-0.595091038827877	0.919464430428377
31	L.3260067	Alchemilla glabra Neygenf.	A_glabra_29	-0.10706820	0.10420010	0.258	1.244	0.804	0.797	1	0.256070490211019	0.662296111558492
32	L.3260076	Alchemilla glabra Neygenf.	A_glabra_30	-0.09450699	0.12220010	0.314	1.242	0.805	0.812	1	-0.139468744826992	0.957271140203855
33	L.3260071	Alchemilla glabra Neygenf.	A_glabra_31	-0.12576860	-0.05811745	0.312	1.346	0.743	0.836	1	0.176691212366252	-0.806969519949898
34	L.3249952	Alchemilla glabra Neygenf.	A_glabra_32	-0.11645860	0.06702033	0.298	1.329	0.752	0.772	1	0.411023816162144	0.077335297045370
35	L.3260127	Alchemilla glabra Neygenf.	A_glabra_33	-0.09133238	0.01920513	0.344	1.416	0.706	0.794	1	0.218995452560774	-0.367955105935304
36	L.3249960	Alchemilla glabra Neygenf.	A_glabra_34	-0.06060205	-0.02861685	0.308	1.311	0.763	0.786	1	-0.017663407165888	-0.379878912222658
37	L.3260169	Alchemilla glabra Neygenf.	A_glabra_35	-0.12933470	0.03901984	0.302	1.373	0.729	0.779	1	0.426563922587984	-0.193589480570792
38	L.3249923	Alchemilla glabra Neygenf.	A_glabra_36	-0.12497460	0.03384893	0.371	1.310	0.764	0.845	1	0.265329447627592	-0.529431914776574
39	L.3260072	Alchemilla glabra Neygenf.	A_glabra_37	-0.05689250	-0.02970317	0.309	1.317	0.759	0.751	1	0.010142972926418	-0.364647183648649
40	L.3260009	Alchemilla glabra Neygenf.	A_glabra_38	-0.15074860	0.01211621	0.343	1.511	0.662	0.806	1	0.534673122742184	-0.701568582234737
41	L.3260151	Alchemilla glabra Neygenf.	A_glabra_39	-0.04641158	-0.02871902	0.362	1.362	0.735	0.809	1	-0.106825730174656	-0.531989228620170
42	L.3249956	Alchemilla glabra Neygenf.	A_glabra_40	0.04550738	0.05500788	0.365	1.174	0.852	0.795	1	-0.641598741227403	0.369445070829563
43	L.3249980	Alchemilla glabra Neygenf.	A_glabra_41	-0.05815263	-0.01205001	0.350	1.336	0.749	0.847	1	-0.090389084937492	-0.447329042402838
44	L.3260149	Alchemilla glabra Neygenf.	A_glabra_42	-0.04886562	0.06067377	0.298	1.324	0.755	0.802	1	0.054503395518346	0.151341867741156
45	L.3260016	Alchemilla glabra Neygenf.	A_glabra_43	-0.00596085	0.15383590	0.294	1.212	0.825	0.792	1	-0.618385370420770	1.211886580029610
46	L.3260196	Alchemilla glabra Neygenf.	A_glabra_44	-0.11422540	-0.03714334	0.291	1.398	0.716	0.809	1	0.249416530890852	-0.594431306873593
47	L.3260209	Alchemilla glabra Neygenf.	A_glabra_45	-0.06391604	0.03449421	0.279	1.375	0.728	0.839	1	0.122730542915016	-0.079862336924127
48	L.3260119	Alchemilla glabra Neygenf.	A_glabra_46	0.03155389	0.10997630	0.380	1.250	0.800	0.843	1	-0.781307768794768	0.758255430320014
49	L.3260188	Alchemilla glabra Neygenf.	A_glabra_47	-0.06748781	0.04698466	0.288	1.484	0.674	0.812	1	0.334786455609747	-0.109834562077295
50	L.3260159	Alchemilla glabra Neygenf.	A_glabra_48	0.05156403	0.09349044	0.260	1.188	0.842	0.837	1	-0.550254385924605	0.694563884082394
51	L.3260125	Alchemilla glabra Neygenf.	A_glabra_49	-0.05894986	-0.11816540	0.283	1.455	0.687	0.795	1	0.085894907278357	-1.162872317683040
52	L.3249986	Alchemilla glabra Neygenf.	A_glabra_50	0.00978500	-0.00086752	0.291	1.237	0.810	0.828	1	-0.327284795051837	-0.060929780963365
53	L.3260122	Alchemilla glabra Neygenf.	A_glabra_51	0.11930820	0.02473633	0.287	1.223	0.818	0.821	1	-0.740298364171440	0.258244227344982
54	L.3249959	Alchemilla glabra Neygenf.	A_glabra_52	-0.00548888	0.06144772	0.369	1.308	0.764	0.861	1	-0.344305489863219	0.191862000909608
55	L.3260008	Alchemilla glabra Neygenf.	A_glabra_53	-0.07470571	-0.01183785	0.359	1.454	0.691	0.849	1	0.073747360956957	-0.626690219964319

56	L.3260150	Alchemilla glabra Neygenf.	A_glabra_54	0.05973697	0.12700950	0.245	1.166	0.857	0.843	1	-0.718026130943916	1.024466312435650
57	L.3260186	Alchemilla glabra Neygenf.	A_glabra_55	0.05938992	0.10630120	0.344	1.277	0.783	0.821	1	-0.676953263497006	0.717324186572469
58	L.3260157	Alchemilla glabra Neygenf.	A_glabra_56	0.11065730	-0.07827312	0.312	1.189	0.841	0.864	1	-1.053207364913550	-0.436694162906909
59	L.3260062	Alchemilla glabra Neygenf.	A_glabra_57	-0.10572430	0.02260905	0.291	1.411	0.713	0.814	1	0.301017614645259	-0.269009969275020
60	L.3260190	Alchemilla glabra Neygenf.	A_glabra_58	0.01650992	0.10103370	0.287	1.198	0.835	0.773	1	-0.387396434878368	0.731138005137505
61	L.3249997	Alchemilla glabra Neygenf.	A_glabra_59	-0.13028470	-0.01286805	0.406	1.520	0.658	0.881	1	0.250780223697048	-1.099869055239770
62	L.3260101	Alchemilla glabra Neygenf.	A_glabra_60	-0.19810450	0.02278671	0.205	1.380	0.724	0.838	1	0.856875065346210	-0.438134060133787
63	L.3260088	Alchemilla glabra Neygenf.	A_glabra_61	-0.09964437	-0.01493454	0.277	1.444	0.694	0.776	1	0.319866395228662	-0.409910499348274
64	L.3249973	Alchemilla glabra Neygenf.	A_glabra_62	0.17004370	-0.03328869	0.289	1.161	0.861	0.848	1	-1.187672108375570	0.012390899916773
65	L.3260022	Alchemilla glabra Neygenf.	A_glabra_63	-0.03750319	-0.04316293	0.280	1.407	0.710	0.769	1	0.036718045265004	-0.438848504612651
66	L.3260173	Alchemilla glabra Neygenf.	A_glabra_64	0.18080900	-0.06721995	0.284	1.131	0.884	0.800	1	-1.382058480949670	-0.114142017274016
67	U.1541786	Alchemilla glabra Neygenf.	A_glabra_65	-0.19385620	0.02516463	0.284	1.356	0.737	0.804	1	0.685062920226946	-0.497387336618869
68	U.1541617	Alchemilla glabra Neygenf.	A_glabra_66	-0.04430262	0.00502393	0.009	1.878	0.532	0.493	2	2.549243174130430	0.165541642395219
69	U.1541616	Alchemilla glabra Neygenf.	A_glabra_67	-0.04316881	0.04473118	0.311	1.411	0.710	0.802	1	0.109159704170918	-0.036334417334546
70	U.1541618	Alchemilla glabra Neygenf.	A_glabra_68	0.15880190	-0.02027132	0.287	1.224	0.817	0.815	1	-1.001379082195170	0.056822129499469
71	U.1542167	Alchemilla glabra Neygenf.	A_glabra_69	0.03522268	-0.10737690	0.245	1.246	0.803	0.820	1	-0.721001730511558	-0.774063958246422
72	U.1541621	Alchemilla glabra Neygenf.	A_glabra_70	-0.01644827	0.04618268	0.233	1.710	0.622	0.699	2	0.997787224483485	-0.074598450698200
73	U.1541812	Alchemilla glabra Neygenf.	A_glabra_71	-0.01352946	-0.00210777	0.428	1.444	0.693	0.887	1	-0.331562228875807	-0.821141510248490
74	U.1541777	Alchemilla glabra Neygenf.	A_glabra_72	-0.06860175	0.01178791	0.297	1.312	0.762	0.787	1	0.065262983980338	-0.153332421359099
75	U.1541766	Alchemilla glabra Neygenf.	A_glabra_73	-0.11181190	0.01585911	0.164	1.476	0.678	0.680	1	0.825089759639329	0.060970923018407
76	U.1542463	Alchemilla glabra Neygenf.	A_glabra_74	0.06962904	0.00378692	0.291	1.364	0.733	0.791	1	-0.402907241757863	-0.018062572674396
77	U.1542469	Alchemilla glabra Neygenf.	A_glabra_75	-0.01619459	0.11626290	0.300	1.212	0.825	0.827	1	-0.431922440298145	0.828547529026214
78	U.1542461	Alchemilla glabra Neygenf.	A_glabra_76	0.01253065	-0.06112296	0.400	1.393	0.718	0.826	1	-0.425605157033723	-0.798350605720663
79	L.4183805	Alchemilla glabra Neygenf.	A_glabra_77	0.07673849	0.01868702	0.298	1.194	0.838	0.852	1	-0.641094158659957	0.145564245539384
80	L.4183455	Alchemilla glabra Neygenf.	A_glabra_78	0.07526340	-0.00969201	0.301	1.208	0.828	0.840	1	-0.643327948234941	-0.028767010613066
81	L.4195116	Alchemilla glabra Neygenf.	A_glabra_79	0.03260441	0.06981377	0.302	1.169	0.855	0.814	1	-0.489637362824695	0.480350433333024
82	L.4195755	Alchemilla glabra Neygenf.	A_glabra_80	-0.06231718	-0.01239167	0.243	1.439	0.695	0.748	1	0.292786446122774	-0.216053925937749
83	L.4228528	Alchemilla glabra Neygenf.	A_glabra_81	-0.07928048	0.07023966	0.343	1.326	0.754	0.796	1	0.228021433563502	0.111774769055066
84	AMD.104512	Alchemilla glabra Neygenf.	A_glabra_82	0.09309563	0.00498626	0.151	1.176	0.852	0.736	1	-0.298139515578940	0.766184142846749
85	L.2074792	Alchemilla glabra Neygenf.	A_glabra_83	-0.04045256	-0.04804386	0.322	1.357	0.738	0.816	1	-0.117966102974711	-0.539355496643391
86	L.2074791	Alchemilla glabra Neygenf.	A_glabra_84	-0.24594610	-0.02720801	0.350	1.510	0.662	0.844	1	0.741610120293789	-1.323852941867320
87	L.3962748	Alchemilla glabra Neygenf.	A_glabra_85	-0.03330761	-0.01944061	0.354	1.499	0.667	0.799	1	0.020096231417921	-0.600884035925541
88	L.3962744	Alchemilla glabra Neygenf.	A_glabra_86	-0.06037296	-0.02572479	0.457	1.452	0.689	0.842	1	-0.154134971347914	-1.077149750962120
89	L.3962750	Alchemilla glabra Neygenf.	A_glabra_87	-0.09456446	0.04909290	0.343	1.423	0.703	0.835	1	0.326219590762746	-0.266212698817464
90	L.3962761	Alchemilla glabra Neygenf.	A_glabra_88	0.01381063	-0.07516273	0.393	1.437	0.696	0.835	1	-0.414234405218748	-0.922816123068215
91	L.3962759	Alchemilla glabra Neygenf.	A_glabra_89	-0.08301253	0.01576833	0.335	1.484	0.674	0.818	1	0.250422228864266	-0.447299402095414
92	L.3962757	Alchemilla glabra Neygenf.	A_glabra_90	0.10298140	-0.02988706	0.286	1.196	0.836	0.840	1	-0.809023508291176	-0.075143927144546
93	L.4317183	Alchemilla glabra Neygenf.	A_glabra_91	-0.03995880	0.03948535	0.276	1.344	0.744	0.825	1	0.012014740020003	0.035713753401750
94	BR0000005077571	Alchemilla glabra Neygenf.	A_glabra_92	0.02040827	-0.02520784	0.299	1.403	0.713	0.815	1	-0.243544172276264	-0.317702249369648
95	BR0000009577824	Alchemilla glabra Neygenf.	A_glabra_93	-0.14936570	-0.03636521	0.372	1.460	0.685	0.871	1	0.280757987119996	-1.024126053710980
96	BR0000010303894	Alchemilla glabra Neygenf.	A_glabra_94	0.07485208	0.06138818	0.266	1.287	0.777	0.791	1	-0.421594097409740	0.438544213772525
97	BR0000010303900	Alchemilla glabra Neygenf.	A_glabra_95	-0.04368359	0.06265544	0.234	1.297	0.771	0.786	1	0.087234140182415	0.317880222727266
98	BR0000010303955	Alchemilla glabra Neygenf.	A_glabra_96	-0.09527186	-0.03002295	0.319	1.422	0.706	0.817	1	0.160925327200132	-0.586145980310424
99	BR0000010303979	Alchemilla glabra Neygenf.	A_glabra_97	-0.06233332	0.02939120	0.253	1.286	0.778	0.789	1	0.092316645947819	0.068084039236021
100	BR0000010303993	Alchemilla glabra Neygenf.	A_glabra_98	-0.12809830	-0.05028641	0.439	1.514	0.660	0.889	1	0.098966093815042	-1.377453737870470
101	BR0000010304006	Alchemilla glabra Neygenf.	A_glabra_99	-0.01256025	0.00692199	0.325	1.330	0.752	0.810	1	-0.174653617717112	-0.167569795894513
102	BR0000010304013	Alchemilla glabra Neygenf.	A_glabra_100	0.04476718	-0.09194505	0.382	1.118	0.895	0.490	2	-1.214804309251740	-1.200402035192800
103	BR0000010304020	Alchemilla glabra Neygenf.	A_glabra_101	-0.02622861	-0.08524866	0.462	1.347	0.742	0.841	1	-0.506655891175841	-1.231495786674600
104	BR0000010304099	Alchemilla glabra Neygenf.	A_glabra_102	0.00316335	-0.00113235	0.301	1.285	0.778	0.793	1	-0.238090567133453	-0.100829766686545
105	BR0000010304112	Alchemilla glabra Neygenf.	A_glabra_103	-0.00595163	-0.12170510	0.304	1.319	0.758	0.835	1	-0.466674268228639	-1.063176906769870
106	BR0000010304129	Alchemilla glabra Neygenf.	A_glabra_104	-0.10244620	0.00522202	0.301	1.414	0.708	0.812	1	0.248700774269687	-0.371373348023717
107	BR0000010304174	Alchemilla glabra Neygenf.	A_glabra_105	0.03019630	0.04425827	0.003	1.394	0.717	0.293	2	1.645282671399440	1.845161896069220
108	BR0000010304273	Alchemilla glabra Neygenf.	A_glabra_106	0.04191477	-0.03431063	0.299	1.210	0.827	0.820	1	-0.545874330700502	-0.209095954881756
109	BR0000010304280	Alchemilla glabra Neygenf.	A_glabra_107	0.13712950	-0.00363073	0.282	1.151	0.869	0.822	1	-0.940247916180373	0.183788175934647
110	BR0000010304303	Alchemilla glabra Neygenf.	A_glabra_108	-0.11825420	0.05800959	0.339	1.418	0.705	0.837	1	0.460220315182390	-0.287164068333109
111	BR0000010304310	Alchemilla glabra Neygenf.	A_glabra_109	0.02160797	-0.08252520	0.216	1.309	0.764	0.729	1	-0.383991451802541	-0.621774362810309
112	BR0000010304433	Alchemilla glabra Neygenf.	A_glabra_110	-0.03483000	0.00497323	0.326	1.353	0.739	0.784	1	-0.055472386072109	-0.215366045827172
113	BR0000010304464	Alchemilla glabra Neygenf.	A_glabra_111	-0.11095110	0.05234809	0.294	1.422	0.703	0.787	1	0.432782379022525	-0.118266147303212
114	BR0000010304501	Alchemilla glabra Neygenf.	A_glabra_112	-0.09969794	-0.03657085	0.264	1.393	0.718	0.773	1	0.287775603466988	-0.466695893429054
115	BR0000010304570	Alchemilla glabra Neygenf.	A_glabra_113	-0.09194293	0.04846003	0.319	1.398	0.715	0.776	1	0.310193002925379	-0.100348068943382
116	BR0000010304594	Alchemilla glabra Neygenf.	A_glabra_114	0.00821498	-0.02374807	0.351	1.320	0.757	0.821	1	-0.336792927425717	-0.360427548436535
117	BR0000010304617	Alchemilla glabra Neygenf.	A_glabra_115	-0.09388450	0.05935258	0.280	1.407	0.711	0.770	1	0.382351473737952	0.023865575399636

118	BR0000010304624	Alchemilla glabra Neygenf.	A_glabra_116	0.01340490	0.06404728	0.322	1.324	0.756	0.818	1	-0.245393013229697	0.255096514989513
119	BR0000010304679	Alchemilla glabra Neygenf.	A_glabra_117	0.00949124	-0.03326689	0.247	1.239	0.807	0.818	1	-0.334600818035465	-0.176145863697542
120	BR0000010304730	Alchemilla glabra Neygenf.	A_glabra_118	-0.18434490	-0.05206119	0.238	1.459	0.686	0.784	1	0.754144934900643	-0.794277617982399
121	BR0000010304778	Alchemilla glabra Neygenf.	A_glabra_119	-0.13338600	-0.03690350	0.331	1.484	0.674	0.817	1	0.348452965329073	-0.810621212578344
122	BR0000010304976	Alchemilla glabra Neygenf.	A_glabra_120	-0.13744330	-0.05827039	0.028	1.404	0.712	0.566	2	1.720421722554520	0.324841550384209
123	BR0000011093558	Alchemilla glabra Neygenf.	A_glabra_121	0.00679104	0.02467417	0.264	1.298	0.773	0.790	1	-0.170969577533150	0.103871452889149
124	BR0000011093886	Alchemilla glabra Neygenf.	A_glabra_122	0.10159830	0.01743407	0.305	1.267	0.790	0.799	1	-0.629439572862407	0.147428265003427
125	BR0000011094845	Alchemilla glabra Neygenf.	A_glabra_123	-0.04885843	-0.01852346	0.295	1.331	0.751	0.772	1	-0.005695487809355	-0.281359609419573
126	BR0000011095170	Alchemilla glabra Neygenf.	A_glabra_124	-0.01085752	-0.07324289	0.275	1.316	0.760	0.822	1	-0.281287200173735	-0.591391327974788
127	BR0000011158059	Alchemilla glabra Neygenf.	A_glabra_125	-0.13852340	0.00766299	0.264	1.433	0.698	0.818	1	0.473181745102968	-0.402704973658392
128	BR0000012123278	Alchemilla glabra Neygenf.	A_glabra_126	-0.15810910	-0.03962359	0.008	1.432	0.698	0.492	2	1.975824333096900	0.537959523234755
129	BR0000012123377	Alchemilla glabra Neygenf.	A_glabra_127	-0.07913894	-0.02670112	0.279	1.481	0.675	0.781	1	0.280096500787411	-0.481351853442136
130	BR0000012312115	Alchemilla glabra Neygenf.	A_glabra_128	-0.12701020	0.02443728	0.358	1.405	0.712	0.839	1	0.325729852276198	-0.557649833350982
131	BR0000012312122	Alchemilla glabra Neygenf.	A_glabra_129	-0.11737990	0.04378442	0.293	1.442	0.693	0.801	1	0.451289968928785	-0.217827524213585
132	BR0000012312139	Alchemilla glabra Neygenf.	A_glabra_130	-0.03769715	0.00055846	0.303	1.330	0.752	0.782	1	-0.046957466191218	-0.179139523269466
133	BR0000012312153	Alchemilla glabra Neygenf.	A_glabra_131	-0.10479500	0.01240923	0.299	1.373	0.729	0.809	1	0.234811385253523	-0.296378781219786
134	BR0000012359721	Alchemilla glabra Neygenf.	A_glabra_132	-0.02414191	0.01832031	0.313	1.268	0.789	0.846	1	-0.200541549090693	-0.078821361355352
135	BR0000012595082	Alchemilla glabra Neygenf.	A_glabra_133	-0.06784362	-0.08653984	0.229	1.377	0.729	0.767	1	0.280548920093913	-0.747749892415446
136	BR0000012595181	Alchemilla glabra Neygenf.	A_glabra_134	-0.10921950	0.02870648	0.266	1.416	0.712	0.801	1	0.376792072393892	-0.187113830741854
137	BR0000012595389	Alchemilla glabra Neygenf.	A_glabra_135	-0.00846210	-0.00977389	0.384	1.434	0.697	0.858	1	-0.238319534889775	-0.580356141485876
138	BR0000012595655	Alchemilla glabra Neygenf.	A_glabra_136	0.06986770	-0.02147844	0.247	1.271	0.788	0.784	1	-0.493204310240314	-0.011061568009872
139	BR0000012595754	Alchemilla glabra Neygenf.	A_glabra_137	-0.01809808	-0.07908294	0.318	1.330	0.752	0.790	1	-0.255318185893067	-0.694770812862303
140	BR0000024647526	Alchemilla glabra Neygenf.	A_glabra_138	-0.14238230	0.01599296	0.281	1.385	0.722	0.758	1	0.487256013773602	-0.294660939526993
141	BR0000025635553V	Alchemilla glabra Neygenf.	A_glabra_139	0.11598930	-0.10401180	0.334	1.273	0.785	0.792	1	-1.043470228824240	-0.713219484436197
142	BR0000026172668V	Alchemilla glabra Neygenf.	A_glabra_140	-0.08918373	-0.00370728	0.306	1.431	0.700	0.780	1	0.228736381773891	-0.383102546961018
143	BR0000026271798V	Alchemilla glabra Neygenf.	A_glabra_141	0.05075720	-0.01162140	0.289	1.324	0.757	0.824	1	-0.407730634539050	-0.123530506177834
144	BR0000026273174V	Alchemilla glabra Neygenf.	A_glabra_142	0.00976900	0.05951479	0.260	1.274	0.785	0.803	1	-0.194327327329786	0.328483202840623
145	BR0000027433041V	Alchemilla glabra Neygenf.	A_glabra_143	-0.04554083	0.03858136	0.286	1.358	0.737	0.797	1	0.060268982257522	0.011139300519439
146	BR0000027433065V	Alchemilla glabra Neygenf.	A_glabra_144	-0.10512390	-0.09093903	0.295	1.469	0.681	0.834	1	0.244738532356775	-1.033025553184130
147	BR0000027433072V	Alchemilla glabra Neygenf.	A_glabra_145	-0.19913660	-0.02473593	0.327	1.606	0.623	0.854	1	0.728484391208842	-1.166785170507200
148	BR0000027433089V	Alchemilla glabra Neygenf.	A_glabra_146	0.02747781	0.06208666	0.367	1.257	0.796	0.840	1	-0.535131560752064	0.294086275692523
149	BR0000027433096V	Alchemilla glabra Neygenf.	A_glabra_147	-0.15423100	-0.07117329	0.297	1.447	0.691	0.859	1	0.393672895851347	-1.024743543677750
150	BR0000027739303V	Alchemilla glabra Neygenf.	A_glabra_148	-0.06197587	0.06406688	0.014	1.203	0.831	0.532	2	1.004877278702520	1.472051815944270
151	BR0000036322763	Alchemilla glabra Neygenf.	A_glabra_149	-0.03406808	0.03518924	0.304	1.246	0.803	0.829	1	-0.142082552550108	0.060651855099711
152	E00128241	Alchemilla glabra Neygenf.	A_glabra_150	0.00795502	0.02100741	0.260	1.352	0.742	0.671	1	0.092730351538513	0.229447895374121
153	E00678057	Alchemilla glabra Neygenf.	A_glabra_151	-0.00553978	-0.06657403	0.277	1.351	0.740	0.829	1	-0.254716159611249	-0.555769116303069
154	E00800447	Alchemilla glabra Neygenf.	A_glabra_152	-0.18150250	0.01932500	0.351	1.435	0.697	0.826	1	0.567537024522142	-0.779903866579871
155	E00800451	Alchemilla glabra Neygenf.	A_glabra_153	-0.06447677	0.02882990	0.291	1.341	0.746	0.784	1	0.105017852228442	-0.062089985611893
156	E00800452	Alchemilla glabra Neygenf.	A_glabra_154	0.00559524	-0.01956769	0.317	1.362	0.734	0.842	1	-0.259552694486257	-0.316949576065656
157	E00800453	Alchemilla glabra Neygenf.	A_glabra_155	-0.03079671	-0.06608355	0.313	1.391	0.719	0.831	1	-0.142624467000878	-0.667874766306389
158	E00800454	Alchemilla glabra Neygenf.	A_glabra_156	-0.17112300	0.00786157	0.234	1.501	0.666	0.773	1	0.781274490354486	-0.466502814456429
159	E00800456	Alchemilla glabra Neygenf.	A_glabra_157	-0.18863520	-0.00668335	0.268	1.405	0.712	0.840	1	0.618151580418474	-0.673457925983151
160	E00800459	Alchemilla glabra Neygenf.	A_glabra_158	0.05737114	0.03697249	0.059	1.170	0.855	0.333	2	0.923587094192372	1.964350076528800
161	E00800464	Alchemilla glabra Neygenf.	A_glabra_159	0.02020992	0.00194572	0.209	1.229	0.815	0.672	1	0.043823441416043	0.420810054293100
162	E00800465	Alchemilla glabra Neygenf.	A_glabra_160	-0.02829713	0.07068213	0.261	1.272	0.786	0.857	1	-0.113717465432697	0.353911006490226
163	E00800466	Alchemilla glabra Neygenf.	A_glabra_161	-0.13536480	0.03874073	0.290	1.503	0.666	0.796	1	0.599891498719528	-0.362848342027588
164	E00800467	Alchemilla glabra Neygenf.	A_glabra_162	-0.06522387	0.04947923	0.272	1.251	0.800	0.829	1	0.039933108863862	0.161306882464256
165	E00800469	Alchemilla glabra Neygenf.	A_glabra_163	-0.04503973	0.04749003	0.006	1.343	0.745	0.392	2	1.491187149110320	1.511619994339220
166	E00800475	Alchemilla glabra Neygenf.	A_glabra_164	0.00908376	0.04998998	0.230	1.180	0.847	0.785	1	-0.227957197384066	0.442410829782937
167	E00800480	Alchemilla glabra Neygenf.	A_glabra_165	-0.09312454	0.00114916	0.263	1.382	0.724	0.797	1	0.239273566827340	-0.255060423166852
168	E00800481	Alchemilla glabra Neygenf.	A_glabra_166	0.12791030	0.08922651	0.196	1.225	0.816	0.879	1	-0.835577892176886	0.878254545680655
169	E00800482	Alchemilla glabra Neygenf.	A_glabra_167	-0.00496168	-0.10203830	0.155	1.273	0.786	0.790	1	-0.311585005816817	-1.049929270191320
170	E00800485	Alchemilla glabra Neygenf.	A_glabra_168	0.01693803	-0.02955289	0.287	1.319	0.758	0.778	1	-0.269444259481439	-0.227427142374708
171	E00800486	Alchemilla glabra Neygenf.	A_glabra_169	0.05843970	-0.05871305	0.276	1.265	0.791	0.823	1	-0.605956444248434	-0.346609629392470
172	E00800487	Alchemilla glabra Neygenf.	A_glabra_170	0.07192669	-0.05836778	0.004	1.817	0.550	0.301	2	2.992268317546350	0.633232507959968
173	E00800491	Alchemilla glabra Neygenf.	A_glabra_171	0.03152734	0.02485278	0.066	1.170	0.855	0.377	2	0.911969292067017	1.711799323898360
174	E00800494	Alchemilla glabra Neygenf.	A_glabra_172	-0.03301372	-0.08105187	0.009	1.227	0.815	0.398	2	1.743213718161280	1.338102409961650
175	E00800495	Alchemilla glabra Neygenf.	A_glabra_173	0.28708070	-0.13270120	0.330	1.132	0.883	0.855	1	-2.341410558249260	-0.612545215929124
176	E00800496	Alchemilla glabra Neygenf.	A_glabra_174	-0.03990329	0.00984386	0.315	1.324	0.755	0.788	1	-0.051637167544377	-0.156812012109425
177	E00800497	Alchemilla glabra Neygenf.	A_glabra_175	-0.05520851	-0.01108473	0.312	1.305	0.767	0.779	1	-0.023225638254840	-0.272945064244415
178	E00800498	Alchemilla glabra Neygenf.	A_glabra_176	-0.04217606	0.03007691	0.255	1.135	0.881	0.328	2	0.619838393437188	1.613042120751350
179	E00829018	Alchemilla glabra Neygenf.	A_glabra_177	0.12073060	-0.08222718	0.236	1.338	0.747	0.760	1	-0.926191991103878	-0.478221318543451

180	E00829023	Alchemilla glabra Neygenf.	A_glabra_178	-0.11400450	-0.04202439	0.249	1.411	0.709	0.801	1	0.371097479320269	-0.547976951337390
181	E00829033	Alchemilla glabra Neygenf.	A_glabra_179	0.10840650	-0.03722322	0.060	1.138	0.878	0.354	2	0.858661827295643	2.024407659728220
182	E00829034	Alchemilla glabra Neygenf.	A_glabra_180	0.02579068	0.10326050	0.307	1.175	0.851	0.863	1	-0.636207360429642	0.728662064688572
183	E00829035	Alchemilla glabra Neygenf.	A_glabra_181	0.01571747	0.03728099	0.364	1.246	0.803	0.845	1	-0.468067132486540	0.057635411140215
184	E00829036	Alchemilla glabra Neygenf.	A_glabra_182	-0.14181250	-0.02580499	0.052	1.270	0.787	0.332	2	1.906629102023010	1.192791541662740
185	E00829043	Alchemilla glabra Neygenf.	A_glabra_183	-0.01923848	0.09580738	0.213	1.237	0.808	0.815	1	-0.119605677903887	0.704264149433022
186	E00829045	Alchemilla glabra Neygenf.	A_glabra_184	0.00922898	-0.06001775	0.417	1.397	0.716	0.836	1	-0.447804645274527	-0.868011192782804
187	E00829046	Alchemilla glabra Neygenf.	A_glabra_185	0.05069143	0.01748535	0.303	1.289	0.776	0.753	1	-0.352397268230305	0.102759634261287
188	E00829051	Alchemilla glabra Neygenf.	A_glabra_186	-0.14661850	-0.02789167	0.009	1.803	0.555	0.392	2	2.817969386987600	0.130262484316896
189	E00829052	Alchemilla glabra Neygenf.	A_glabra_187	-0.07071745	-0.07771555	0.333	1.514	0.664	0.832	1	0.106199929432943	-0.985371154448967
190	E00829053	Alchemilla glabra Neygenf.	A_glabra_188	-0.08178923	-0.02129604	0.228	1.361	0.735	0.792	1	0.252406237387056	-0.259703835337779
191	E00829055	Alchemilla glabra Neygenf.	A_glabra_189	0.09200950	0.00251046	0.074	1.185	0.844	0.410	2	0.714997140432888	1.701381336139390
192	E00829057	Alchemilla glabra Neygenf.	A_glabra_190	-0.25547220	-0.07484375	0.301	1.587	0.630	0.875	1	0.878862470344791	-1.598796406963300
193	E00829060	Alchemilla glabra Neygenf.	A_glabra_191	-0.11839830	-0.06801973	0.023	1.581	0.632	0.515	2	2.056207144643950	0.181858081864677
194	E00829067	Alchemilla glabra Neygenf.	A_glabra_192	-0.09105489	0.05165402	0.325	1.286	0.778	0.844	1	0.172731268643257	-0.017894679687920
195	E00829068	Alchemilla glabra Neygenf.	A_glabra_193	-0.04023373	-0.02033234	0.247	1.261	0.793	0.753	1	0.009470175408262	-0.100074665146733
196	E00829070	Alchemilla glabra Neygenf.	A_glabra_194	-0.04944180	-0.06344487	0.247	1.144	0.874	0.845	1	-0.425215880795647	-0.639762390996973
197	E00829071	Alchemilla glabra Neygenf.	A_glabra_195	0.03333764	-0.01119004	0.006	1.716	0.583	0.401	2	2.292035795849320	0.783476554404298
198	E00829073	Alchemilla glabra Neygenf.	A_glabra_196	0.01958089	0.04375357	0.322	1.265	0.791	0.835	1	-0.352107398001110	0.150913525506737
199	E00829074	Alchemilla glabra Neygenf.	A_glabra_197	-0.03255691	0.01062416	0.053	1.254	0.797	0.457	2	1.110351475223910	1.198402927094740
200	E00829076	Alchemilla glabra Neygenf.	A_glabra_198	-0.02556956	0.03529509	0.244	1.277	0.793	0.605	1	0.282937673760903	0.452544915980118
201	E00829078	Alchemilla glabra Neygenf.	A_glabra_199	-0.09376993	-0.03187072	0.015	1.714	0.584	0.458	2	2.302109076043140	0.304784492122902
202	E00829079	Alchemilla glabra Neygenf.	A_glabra_200	-0.11836070	-0.02437020	0.253	1.352	0.742	0.606	1	0.719795699686720	-0.109855543049139
203	E00829080	Alchemilla glabra Neygenf.	A_glabra_201	0.08374601	-0.08956982	0.308	1.482	0.675	0.820	1	-0.633871161392865	-0.888752401090486
204	E00829083	Alchemilla glabra Neygenf.	A_glabra_202	0.12912320	-0.04036938	0.310	1.181	0.846	0.833	1	-0.990004576410244	-0.127530793303488
205	E00829084	Alchemilla glabra Neygenf.	A_glabra_203	-0.16704680	0.00764809	0.256	1.432	0.698	0.761	1	0.657783789104713	-0.407601084423092
206	E00829085	Alchemilla glabra Neygenf.	A_glabra_204	-0.05888654	0.02069028	0.008	1.401	0.714	0.410	2	1.631002949715900	1.218228492493780
207	E00829086	Alchemilla glabra Neygenf.	A_glabra_205	-0.04558888	0.04563184	0.369	1.286	0.778	0.833	1	-0.108288319841944	-0.045730669774588
208	E00829088	Alchemilla glabra Neygenf.	A_glabra_206	0.04643837	-0.04113650	0.288	1.356	0.738	0.838	1	-0.432932319796168	-0.339060216324098
209	E00829092	Alchemilla glabra Neygenf.	A_glabra_207	0.02151910	-0.02529699	0.343	1.311	0.765	0.783	1	-0.358927141538883	-0.304914967744134
210	E00829093	Alchemilla glabra Neygenf.	A_glabra_208	-0.03703819	0.03750337	0.350	1.303	0.770	0.811	1	-0.099172266092688	-0.055324868464525
211	E00829094	Alchemilla glabra Neygenf.	A_glabra_209	-0.06653039	-0.03632389	0.333	1.295	0.772	0.787	1	-0.049025281139889	-0.493770392529809
212	E00829095	Alchemilla glabra Neygenf.	A_glabra_210	-0.08991131	-0.09733867	0.281	1.138	0.878	0.361	2	1.815972468062310	-0.110313865643695
213	E00829096	Alchemilla glabra Neygenf.	A_glabra_211	-0.11047080	-0.03605190	0.012	1.288	0.776	0.389	2	1.835873557017700	1.145740802258250
214	E00829098	Alchemilla glabra Neygenf.	A_glabra_212	0.05354449	-0.08200275	0.348	1.278	0.782	0.849	1	-0.712779953715234	-0.660928345616719
215	E00829099	Alchemilla glabra Neygenf.	A_glabra_213	-0.02776849	-0.02715054	0.302	1.441	0.694	0.861	1	-0.069668708240448	-0.482051119206519
216	E01153123	Alchemilla glabra Neygenf.	A_glabra_214	-0.14672320	-0.09838006	0.455	1.519	0.658	0.888	1	0.053620660890237	-1.772043492301980
217	E01153124	Alchemilla glabra Neygenf.	A_glabra_215	-0.06789101	-0.03670838	0.019	1.590	0.630	0.388	2	2.156208128143970	0.677838108706867
218	E01153126	Alchemilla glabra Neygenf.	A_glabra_216	-0.12954470	-0.02420272	0.215	1.451	0.689	0.769	1	0.605783903098005	-0.401211138632920
219	E01153127	Alchemilla glabra Neygenf.	A_glabra_217	0.02315907	0.03405887	0.017	1.367	0.732	0.572	2	0.958107050623103	1.168244351692920
220	E01153128	Alchemilla glabra Neygenf.	A_glabra_218	0.06140074	-0.06595710	0.359	1.377	0.726	0.843	1	-0.610443476986133	-0.649260797123812
221	E01153131	Alchemilla glabra Neygenf.	A_glabra_219	-0.01781234	0.03897397	0.318	1.241	0.810	0.563	1	0.231206103129507	0.584325853984500
222	E01153133	Alchemilla glabra Neygenf.	A_glabra_220	0.02018099	0.01813415	0.436	1.377	0.726	0.849	1	-0.571895504970969	-0.579117213197352
223	E01153135	Alchemilla glabra Neygenf.	A_glabra_221	-0.07316500	0.04923557	0.307	1.341	0.745	0.804	1	0.151477866467933	0.001254857093867
224	KRAM304648	Alchemilla glabra Neygenf.	A_glabra_222	-0.05430996	-0.01433506	0.311	1.337	0.748	0.777	1	-0.000413353175361	-0.305953927622013
225	KRAM323266	Alchemilla glabra Neygenf.	A_glabra_223	0.08378059	-0.01947770	0.305	1.246	0.802	0.848	1	-0.665651661964654	-0.109801467262115
226	KRAM323272	Alchemilla glabra Neygenf.	A_glabra_224	-0.17875360	-0.03477584	0.301	1.383	0.723	0.813	1	0.489193645042316	-0.797221382275523
227	KRAM323273	Alchemilla glabra Neygenf.	A_glabra_225	-0.11732370	-0.02976118	0.338	1.436	0.700	0.817	1	0.233541879924705	-0.698723043894362
228	KRAM323275	Alchemilla glabra Neygenf.	A_glabra_226	0.10580250	0.02452004	0.231	1.148	0.871	0.793	1	-0.685248219201210	0.448761384761138
229	KRAM323448	Alchemilla glabra Neygenf.	A_glabra_227	0.00724265	-0.09314579	0.372	1.518	0.659	0.797	1	-0.241083721801357	-1.122422903028020
230	KRAM323449	Alchemilla glabra Neygenf.	A_glabra_228	0.04262827	-0.04098603	0.002	1.447	0.691	0.232	2	2.174024333917420	1.630189842957230
231	KRAM323452	Alchemilla glabra Neygenf.	A_glabra_229	0.01177663	0.00144444	0.423	1.387	0.721	0.823	1	-0.442259332419762	-0.571666347633886
232	KRAM323458	Alchemilla glabra Neygenf.	A_glabra_230	0.10055500	-0.01384314	0.376	1.292	0.778	0.829	1	-0.801290294068802	-0.229963975313232
233	KRAM323466	Alchemilla glabra Neygenf.	A_glabra_231	-0.00232855	-0.04987802	0.316	1.350	0.741	0.834	1	-0.275238983812630	-0.485265080740160
234	KRAM323476	Alchemilla glabra Neygenf.	A_glabra_232	-0.02908737	-0.00325364	0.466	1.397	0.717	0.818	1	-0.330144021617581	-0.930141175208988
235	KRAM323480	Alchemilla glabra Neygenf.	A_glabra_233	0.15734680	-0.08035586	0.360	1.240	0.807	0.854	1	-1.266474481997880	-0.514490710644337
236	KRAM329440	Alchemilla glabra Neygenf.	A_glabra_234	-0.21618100	-0.03949523	0.300	1.554	0.643	0.826	1	0.783692549537603	-1.116886978234650
237	KRAM329446	Alchemilla glabra Neygenf.	A_glabra_235	-0.04495847	-0.02333186	0.438	1.315	0.760	0.784	1	-0.281684559832600	-0.800788802714902
238	KRAM329448	Alchemilla glabra Neygenf.	A_glabra_236	-0.15639310	0.02602043	0.346	1.435	0.697	0.848	1	0.479789078514232	-0.664760058411854
239	KRAM397299	Alchemilla glabra Neygenf.	A_glabra_237	-0.10679400	0.02209521	0.333	1.456	0.687	0.798	1	0.342790181170522	-0.406924716857034
240	UGDA.0040842	Alchemilla glabra Neygenf.	A_glabra_238	-0.02950072	0.00080395	0.321	1.383	0.724	0.816	1	-0.075681726178226	-0.268874174134448
241	BR0000010929575	Alchemilla glaucescens Wallr.	A_glaucescens_1	-0.06882280	0.07169726	0.198	1.283	0.780	0.832	1	0.210795308133297	0.433188815787040

242	BR0000010929759	Alchemilla glaucescens Wallr.	A_glaucescens_2	0.05018013	-0.06898426	0.217	1.310	0.763	0.836	1	-0.591336699364481	-0.447051019958726
243	BR0000010930052	Alchemilla glaucescens Wallr.	A_glaucescens_3	0.29929950	-0.01526477	0.183	1.132	0.883	0.807	1	-1.846781111326920	0.762656787386143
244	BR0000010930083	Alchemilla glaucescens Wallr.	A_glaucescens_4	0.18435640	-0.03328812	0.188	1.180	0.847	0.820	1	-1.248747854741140	0.327118580994395
245	BR0000010971529	Alchemilla glaucescens Wallr.	A_glaucescens_5	0.00527956	-0.03075841	0.238	1.340	0.749	0.818	1	-0.184590885609880	-0.217936485195837
246	BR0000011093244	Alchemilla glaucescens Wallr.	A_glaucescens_6	0.14309740	0.00451882	0.184	1.182	0.846	0.829	1	-0.912384346712152	0.468827985215307
247	BR0000011094272	Alchemilla glaucescens Wallr.	A_glaucescens_7	0.04344692	-0.01013095	0.222	1.294	0.774	0.829	1	-0.341048462403903	0.029675108032260
248	BR0000011094302	Alchemilla glaucescens Wallr.	A_glaucescens_8	0.12577980	0.06505545	0.207	1.169	0.856	0.841	1	-0.790865337328004	0.719374198063009
249	BR0000011094395	Alchemilla glaucescens Wallr.	A_glaucescens_9	0.04252438	0.05804256	0.196	1.165	0.858	0.821	1	-0.382059824010419	0.613591302223107
250	BR0000011094579	Alchemilla glaucescens Wallr.	A_glaucescens_10	0.01337044	-0.00042454	0.222	1.490	0.671	0.834	1	0.134343565263416	-0.104985782249148
251	BR0000011094630	Alchemilla glaucescens Wallr.	A_glaucescens_11	0.04458581	0.03079752	0.205	1.210	0.826	0.795	1	-0.301769138025027	0.409905939021263
252	BR0000011094722	Alchemilla glaucescens Wallr.	A_glaucescens_12	0.09981289	0.06796979	0.196	1.227	0.816	0.805	1	-0.524071662009172	0.721391472288250
253	BR0000011094753	Alchemilla glaucescens Wallr.	A_glaucescens_13	0.00204220	0.04431923	0.261	1.331	0.753	0.853	1	-0.162910682280261	0.160823951922026
254	BR0000011094937	Alchemilla glaucescens Wallr.	A_glaucescens_14	-0.05917268	0.05592480	0.256	1.411	0.713	0.846	1	0.224590603033215	0.069016840634000
255	BR0000011094968	Alchemilla glaucescens Wallr.	A_glaucescens_15	0.20252170	-0.04513594	0.228	1.249	0.801	0.823	1	-1.317408268739280	0.069396042586929
256	BR0000011095385	Alchemilla glaucescens Wallr.	A_glaucescens_16	0.05248734	0.04436367	0.199	1.172	0.853	0.817	1	-0.400638720399864	0.537714944946036
257	BR0000011095415	Alchemilla glaucescens Wallr.	A_glaucescens_17	0.12805980	0.04377658	0.254	1.190	0.841	0.834	1	-0.789244371453081	0.464217420918303
258	BR0000011096153	Alchemilla glaucescens Wallr.	A_glaucescens_18	0.03098454	0.07011274	0.238	1.236	0.810	0.813	1	-0.301127455981295	0.501266347421397
259	BR0000012291076	Alchemilla glaucescens Wallr.	A_glaucescens_19	0.09464873	0.02401303	0.290	1.289	0.776	0.839	1	-0.597395348668695	0.155629201303396
260	BR0000012444038	Alchemilla glaucescens Wallr.	A_glaucescens_20	0.14398020	-0.15099640	0.281	1.182	0.846	0.787	1	-1.497374806587090	-0.970994397941493
261	BR0000012594511	Alchemilla glaucescens Wallr.	A_glaucescens_21	0.18734950	-0.01654566	0.256	1.238	0.808	0.853	1	-1.157312834761130	0.148171450185297
262	BR0000012595488	Alchemilla glaucescens Wallr.	A_glaucescens_22	0.24772100	0.02218789	0.285	1.208	0.827	0.871	1	-1.503849369761140	0.451244840683935
263	BR0000025302288V	Alchemilla glaucescens Wallr.	A_glaucescens_23	-0.10087660	-0.05835638	0.249	1.484	0.674	0.815	1	0.392971910089908	-0.706699445435812
264	BR0000025302295V	Alchemilla glaucescens Wallr.	A_glaucescens_24	-0.03059462	0.03266826	0.296	1.294	0.773	0.830	1	-0.105390130723914	0.012999550806401
265	BR0000025302332V	Alchemilla glaucescens Wallr.	A_glaucescens_25	0.18304700	0.00767569	0.221	1.236	0.811	0.813	1	-1.034604644654400	0.426268682522741
266	BR0000026172682V	Alchemilla glaucescens Wallr.	A_glaucescens_26	0.05947681	-0.04568268	0.159	1.302	0.768	0.813	1	-0.641647023126876	-0.165142924101228
267	E00093039	Alchemilla glaucescens Wallr.	A_glaucescens_27	0.04499517	-0.02649849	0.020	1.462	0.684	0.479	2	1.453827694814830	1.057096655590210
268	E00639970	Alchemilla glaucescens Wallr.	A_glaucescens_28	0.13091450	0.00473735	0.301	1.260	0.794	0.844	1	-0.825820235532017	0.091825862876215
269	E00678066	Alchemilla glaucescens Wallr.	A_glaucescens_29	0.04977597	0.06930914	0.048	1.233	0.811	0.364	2	0.935815132912589	1.931244386895720
270	E00678067	Alchemilla glaucescens Wallr.	A_glaucescens_30	0.03012304	-0.01032620	0.159	2.921	0.342	0.424	2	8.308848367863170	-2.682485562252520
271	E00678068	Alchemilla glaucescens Wallr.	A_glaucescens_31	-0.04219111	-0.00484548	0.018	1.785	0.560	0.400	2	2.473623326891970	0.479472584033772
272	E00678069	Alchemilla glaucescens Wallr.	A_glaucescens_32	0.15467390	0.01595584	0.281	1.023	0.977	0.844	1	-1.223302337333890	0.442752429975233
273	E00678070	Alchemilla glaucescens Wallr.	A_glaucescens_33	0.12913560	0.06391037	0.310	1.206	0.829	0.825	1	-0.849992064223817	0.514460925729294
274	E00678071	Alchemilla glaucescens Wallr.	A_glaucescens_34	0.07381516	-0.01312546	0.289	1.284	0.779	0.837	1	-0.549023193067652	-0.080536818567309
275	E00678074	Alchemilla glaucescens Wallr.	A_glaucescens_35	0.11312340	0.00869210	0.341	1.239	0.807	0.861	1	-0.837583407133426	0.028141941708940
276	E01153145	Alchemilla glaucescens Wallr.	A_glaucescens_36	0.03758912	0.06016014	0.017	1.230	0.813	0.353	2	1.098040550558070	1.982791500310390
277	E01153147	Alchemilla glaucescens Wallr.	A_glaucescens_37	0.00446310	-0.01028509	0.010	1.922	0.520	0.327	2	3.064337416674550	0.415318533882258
278	E01153149	Alchemilla glaucescens Wallr.	A_glaucescens_38	-0.05475496	0.00308098	0.222	1.282	0.780	0.858	1	0.037735483321181	-0.046658486790600
279	E01153151	Alchemilla glaucescens Wallr.	A_glaucescens_39	0.16599370	-0.07274702	0.290	1.201	0.833	0.840	1	-1.254409998583220	-0.274314774400729
280	E01153152	Alchemilla glaucescens Wallr.	A_glaucescens_40	0.10470990	0.09884849	0.291	1.193	0.838	0.840	1	-0.820316304309784	0.756240055210886
281	E01153153	Alchemilla glaucescens Wallr.	A_glaucescens_41	0.13083970	0.01202109	0.161	1.420	0.734	0.684	1	0.070922018239871	0.845742535248603
282	E01153218	Alchemilla glaucescens Wallr.	A_glaucescens_42	0.09085570	-0.01943804	0.267	1.224	0.817	0.823	1	-0.672008127790943	-0.006276009393083
283	E01153312	Alchemilla glaucescens Wallr.	A_glaucescens_43	0.10255150	-0.08997903	0.202	1.404	0.715	0.707	1	-0.823646474863820	-0.747538619730188
284	KRAM 62190	Alchemilla glaucescens Wallr.	A_glaucescens_44	-0.09296138	-0.06335401	0.351	1.145	0.873	0.869	1	-0.360234777217467	-0.966417829507299
285	KRAM00028870-V	Alchemilla glaucescens Wallr.	A_glaucescens_45	-0.09453189	0.04689216	0.026	2.736	0.366	0.487	2	7.834195670621410	-1.246677321738150
286	KRAM00028872-V	Alchemilla glaucescens Wallr.	A_glaucescens_46	0.12164270	-0.02987311	0.261	1.241	0.808	0.667	1	-0.800390825465735	0.232075290114509
287	KRAM00028878-V	Alchemilla glaucescens Wallr.	A_glaucescens_47	0.05772728	0.25652980	0.431	1.183	0.845	0.847	1	-2.606908427233470	1.599663902968370
288	KRAM00028880-V	Alchemilla glaucescens Wallr.	A_glaucescens_48	-0.01854980	0.10643230	0.324	1.212	0.825	0.791	1	-0.372206846848737	0.748323315506048
289	KRAM323223	Alchemilla glaucescens Wallr.	A_glaucescens_49	0.00024815	0.00652975	0.199	1.358	0.738	0.711	1	0.180189964938244	0.233001533365183
290	KRAM323233	Alchemilla glaucescens Wallr.	A_glaucescens_50	0.04812316	-0.02063560	0.220	1.226	0.816	0.821	1	-0.473815380804289	0.027671441980515
291	KRAM323240	Alchemilla glaucescens Wallr.	A_glaucescens_51	0.02106960	0.02007627	0.234	1.282	0.780	0.817	1	-0.225548429394630	0.154608793532443
292	KRAM328232	Alchemilla glaucescens Wallr.	A_glaucescens_52	0.09053448	-0.02909315	0.234	1.223	0.822	0.590	1	0.005691173133530	0.751882147795851
293	UGDA.0137789	Alchemilla hybrida (L.) L.	A_hybrida_1	-0.06706599	-0.06359047	0.351	1.472	0.686	0.837	1	0.023102074135170	-0.872686272508454
294	WAG.1503755	Alchemilla mollis (Buser) Rothm.	A_mollis_1	0.01932922	0.06922636	0.282	1.313	0.762	0.871	1	-0.308277098261844	0.341157119829866
295	WAG.1503754	Alchemilla mollis (Buser) Rothm.	A_mollis_2	0.15604650	-0.03769872	0.308	1.169	0.855	0.912	1	-1.211023496799640	-0.121602222355896
296	L.3249853	Alchemilla mollis (Buser) Rothm.	A_mollis_3	0.17947080	0.02330609	0.376	1.133	0.883	0.882	1	-1.401388880473180	0.224696259427281
297	L.3249862	Alchemilla mollis (Buser) Rothm.	A_mollis_4	0.16243040	-0.02800746	0.427	1.202	0.832	0.905	1	-1.442249530005180	-0.323243253276105
298	L.3249857	Alchemilla mollis (Buser) Rothm.	A_mollis_5	0.13572530	-0.01190387	0.187	1.691	0.647	0.654	2	1.180857088591750	0.269032304181568
299	L.4228533	Alchemilla mollis (Buser) Rothm.	A_mollis_6	-0.11861530	0.04263724	0.283	1.344	0.744	0.879	1	0.347570487460964	-0.181120667409836
300	L.4228514	Alchemilla mollis (Buser) Rothm.	A_mollis_7	-0.03379938	0.02376197	0.393	1.311	0.763	0.898	1	-0.365433355464674	-0.462944916729227
301	323298	Alchemilla mollis (Buser) Rothm.	A_mollis_8	0.01255439	-0.06558314	0.047	1.145	0.873	0.310	2	1.490967857913780	1.793770712060670
302	E00441087	Alchemilla mollis (Buser) Rothm.	A_mollis_9	-0.16731150	-0.05506021	0.286	1.319	0.758	0.834	1	0.391430776495464	-0.873627467384611
303	E00441088	Alchemilla mollis (Buser) Rothm.	A_mollis_10	0.18945570	-0.00225514	0.284	1.131	0.884	0.893	1	-1.309804691838950	0.224371581464075

304	E00441092	Alchemilla mollis (Buser) Rothm.	A_mollis_11	-0.11937330	0.05790026	0.325	1.320	0.757	0.840	1	0.367120375072514	-0.102656345176460
305	E00678083	Alchemilla mollis (Buser) Rothm.	A_mollis_12	-0.03228939	-0.01275643	0.319	1.284	0.779	0.867	1	-0.215830454160187	-0.313838295255879
306	E00829103	Alchemilla mollis (Buser) Rothm.	A_mollis_13	0.05416778	0.06012333	0.340	1.332	0.751	0.885	1	-0.574561116573763	0.257937214434813
307	E00829104	Alchemilla mollis (Buser) Rothm.	A_mollis_14	-0.08217534	-0.06238577	0.242	1.186	0.843	0.314	2	1.574395933373850	0.905972849618138
308	E00829105	Alchemilla mollis (Buser) Rothm.	A_mollis_15	0.09049777	0.04943466	0.226	1.134	0.882	0.289	2	0.266711943503093	2.075348999718760
309	E00829106	Alchemilla mollis (Buser) Rothm.	A_mollis_16	0.05878191	0.04738011	0.383	1.125	0.889	0.490	2	-0.436385496422093	1.297548936879550
310	E00829107	Alchemilla mollis (Buser) Rothm.	A_mollis_17	0.03327709	0.01815901	0.391	1.218	0.823	0.901	1	-0.750688084590752	-0.198531430373749
311	E00829109	Alchemilla mollis (Buser) Rothm.	A_mollis_18	-0.20567990	-0.01667462	0.363	1.482	0.675	0.883	1	0.534865709051961	-1.180462859519880
312	E01153251	Alchemilla mollis (Buser) Rothm.	A_mollis_19	-0.07204139	-0.07618662	0.371	1.408	0.710	0.879	1	-0.105843611939830	-1.003811871594140
313	K000914197	Alchemilla mollis (Buser) Rothm.	A_mollis_20	0.12429520	-0.00944455	0.469	1.236	0.810	0.898	1	-1.382307053324420	-0.430574624794927
314	323616	Alchemilla monticola Opiz	A_monticola_1	-0.04402625	0.04867766	0.299	1.306	0.766	0.809	1	-0.007421562745763	0.092490413646841
315	323633	Alchemilla monticola Opiz	A_monticola_2	0.01551669	-0.10887170	0.285	1.226	0.815	0.808	1	-0.650589887784666	-0.830410430447434
316	323728	Alchemilla monticola Opiz	A_monticola_3	0.12432030	-0.03685681	0.257	1.173	0.853	0.833	1	-0.944301019677614	-0.016464501974198
317	325064	Alchemilla monticola Opiz	A_monticola_4	0.02783308	-0.00106391	0.257	1.203	0.832	0.785	1	-0.341221784238332	0.094387880320091
318	329303	Alchemilla monticola Opiz	A_monticola_5	0.12130100	0.10748520	0.275	1.089	0.919	0.841	1	-1.025471157867050	0.945222838703920
319	3560	Alchemilla monticola Opiz	A_monticola_6	0.01172749	0.07076184	0.326	1.215	0.823	0.831	1	-0.424162610197771	0.396455856357983
320	57916	Alchemilla monticola Opiz	A_monticola_7	0.10697980	-0.09150070	0.249	1.196	0.836	0.807	1	-1.047883385588530	-0.451536667067051
321	57972	Alchemilla monticola Opiz	A_monticola_8	0.11571350	-0.08093891	0.310	1.295	0.772	0.809	1	-0.921305925805717	-0.511944632508624
322	60726	Alchemilla monticola Opiz	A_monticola_9	0.14087210	0.01925147	0.238	1.170	0.855	0.836	1	-0.888124720148153	0.383549444223396
323	61045	Alchemilla monticola Opiz	A_monticola_10	-0.03133248	0.03810605	0.264	1.258	0.795	0.811	1	-0.081688127811955	0.148871225012585
324	62346	Alchemilla monticola Opiz	A_monticola_11	-0.01739419	-0.02148390	0.346	1.442	0.694	0.830	1	-0.128654584533974	-0.501679126197399
325	62348	Alchemilla monticola Opiz	A_monticola_12	0.08990650	-0.01858662	0.302	1.228	0.814	0.829	1	-0.688453599681060	-0.066339157977754
326	62361	Alchemilla monticola Opiz	A_monticola_13	0.04175530	0.03393038	0.307	1.221	0.819	0.821	1	-0.447685530077122	0.178366702953096
327	66187	Alchemilla monticola Opiz	A_monticola_14	-0.06714404	-0.05818125	0.353	1.452	0.689	0.826	1	0.014377231631254	-0.813240388004872
328	BR0000006357207	Alchemilla monticola Opiz	A_monticola_15	-0.04543882	-0.05257700	0.300	1.385	0.722	0.811	1	-0.045923574738020	-0.557035609109259
329	BR0000006357405	Alchemilla monticola Opiz	A_monticola_16	0.01241062	0.06110851	0.220	1.231	0.822	0.829	1	-0.231298408169585	0.457393592801962
330	BR0000006357443	Alchemilla monticola Opiz	A_monticola_17	-0.10144630	-0.01410517	0.012	1.318	0.759	0.543	2	1.452109481237440	0.823769738043433
331	BR0000006357498	Alchemilla monticola Opiz	A_monticola_18	0.01034439	0.20289650	0.242	1.107	0.903	0.821	1	-1.092399200831670	1.784316426966240
332	BR0000006357528	Alchemilla monticola Opiz	A_monticola_19	0.09201016	-0.02113151	0.235	1.153	0.867	0.832	1	-0.785488014927860	0.099449074962826
333	BR0000006371265	Alchemilla monticola Opiz	A_monticola_20	-0.00948197	-0.01280420	0.211	1.280	0.789	0.805	1	-0.077354924718076	0.024825480629103
334	BR0000006371272	Alchemilla monticola Opiz	A_monticola_21	0.05114292	0.05946383	0.107	1.261	0.795	0.590	2	0.336251237057171	1.115865240372360
335	BR0000006931254	Alchemilla monticola Opiz	A_monticola_22	0.04430444	0.02623049	0.239	1.236	0.809	0.852	1	-0.400345668193091	0.226761751093134
336	BR0000006931520	Alchemilla monticola Opiz	A_monticola_23	-0.07806268	-0.00980227	0.261	1.369	0.732	0.786	1	0.176187751746216	-0.256425866010479
337	BR0000008141354	Alchemilla monticola Opiz	A_monticola_24	-0.01013867	0.04769205	0.300	1.307	0.765	0.795	1	-0.128352503108853	0.145194475531805
338	BR0000008141422	Alchemilla monticola Opiz	A_monticola_25	0.00100226	-0.00484017	0.339	1.410	0.709	0.816	1	-0.185560497852455	-0.321635610619464
339	BR0000008141439	Alchemilla monticola Opiz	A_monticola_26	0.08370238	0.03660233	0.221	1.195	0.837	0.797	1	-0.512167405679871	0.461006988013051
340	BR0000009408838	Alchemilla monticola Opiz	A_monticola_27	0.06121870	-0.09227145	0.330	1.347	0.743	0.835	1	-0.672312980250139	-0.749700548466164
341	BR0000009721616	Alchemilla monticola Opiz	A_monticola_28	0.01195871	-0.01780161	0.225	1.245	0.804	0.795	1	-0.238813845425109	0.014996376220841
342	BR0000009916753	Alchemilla monticola Opiz	A_monticola_29	0.01156644	-0.04264466	0.215	1.365	0.733	0.775	1	-0.089728395324165	-0.231057732374288
343	BR0000009916777	Alchemilla monticola Opiz	A_monticola_30	0.04904430	-0.03269299	0.286	1.294	0.773	0.836	1	-0.474896063949194	-0.227895019029604
344	BR0000009916845	Alchemilla monticola Opiz	A_monticola_31	0.08658065	0.14189480	0.276	1.134	0.882	0.849	1	-0.990524513918499	1.142520325412460
345	BR0000009916920	Alchemilla monticola Opiz	A_monticola_32	-0.01850264	0.08594932	0.294	1.248	0.801	0.802	1	-0.178734512589999	0.496237787517477
346	BR0000009916968	Alchemilla monticola Opiz	A_monticola_33	-0.11143610	0.01291156	0.330	1.322	0.757	0.816	1	0.192799050508323	-0.353529205922872
347	BR0000009917026	Alchemilla monticola Opiz	A_monticola_34	0.00436662	-0.01581931	0.279	1.293	0.775	0.825	1	-0.259379854428328	-0.166643029561146
348	BR0000009987630	Alchemilla monticola Opiz	A_monticola_35	-0.00839699	-0.08872360	0.014	1.264	0.791	0.335	2	1.888113081481000	1.460789058192220
349	BR0000009987647	Alchemilla monticola Opiz	A_monticola_36	-0.01737667	0.02215971	0.224	1.266	0.790	0.775	1	-0.035920357120889	0.189033203193888
350	BR0000009987678	Alchemilla monticola Opiz	A_monticola_37	0.04331283	0.00343452	0.229	1.262	0.793	0.765	1	-0.265723750354010	0.180510219161769
351	BR0000011093411	Alchemilla monticola Opiz	A_monticola_38	0.14095000	0.00778064	0.265	1.180	0.849	0.845	1	-0.914297345519240	0.244018894260593
352	BR0000011093770	Alchemilla monticola Opiz	A_monticola_39	0.03836216	-0.00072787	0.129	1.277	0.785	0.641	1	0.340770599805745	0.696542350886790
353	BR0000011094104	Alchemilla monticola Opiz	A_monticola_40	0.16240440	-0.06890967	0.350	1.214	0.823	0.875	1	-1.283701523909000	-0.399002224516460
354	BR0000011094784	Alchemilla monticola Opiz	A_monticola_41	-0.00512897	-0.00938732	0.327	1.300	0.769	0.825	1	-0.261119109881405	-0.237608042333195
355	BR0000011095088	Alchemilla monticola Opiz	A_monticola_42	-0.00936006	0.03100441	0.344	1.290	0.777	0.857	1	-0.272729281690901	-0.059609501902840
356	BR0000011095118	Alchemilla monticola Opiz	A_monticola_43	-0.08164609	-0.02855470	0.331	1.343	0.745	0.834	1	0.013163019438707	-0.533633111152204
357	BR0000011095378	Alchemilla monticola Opiz	A_monticola_44	0.10032750	-0.00641482	0.015	1.272	0.786	0.497	2	0.868207639601274	1.576893125166940
358	BR0000011095644	Alchemilla monticola Opiz	A_monticola_45	0.06891068	0.03166814	0.288	1.263	0.792	0.846	1	-0.512851979363949	0.178248401621346
359	BR0000011095910	Alchemilla monticola Opiz	A_monticola_46	0.06085874	0.02848264	0.286	1.236	0.810	0.844	1	-0.503356014931226	0.172187074032066
360	BR0000011095972	Alchemilla monticola Opiz	A_monticola_47	0.06573330	0.04496552	0.289	1.197	0.837	0.840	1	-0.562791462159105	0.310454712935672
361	BR0000011096061	Alchemilla monticola Opiz	A_monticola_48	0.08916359	-0.01744769	0.268	1.229	0.814	0.783	1	-0.623134363488370	0.030312679480266
362	BR0000012311989	Alchemilla monticola Opiz	A_monticola_49	-0.03907741	-0.06103125	0.343	1.402	0.714	0.864	1	-0.157350308478556	-0.744088586097757
363	BR0000012312023	Alchemilla monticola Opiz	A_monticola_50	-0.08939950	0.05421678	0.303	1.371	0.729	0.818	1	0.260240325506814	-0.040054169603796
364	BR0000012312047	Alchemilla monticola Opiz	A_monticola_51	0.10574090	-0.01242394	0.350	1.215	0.824	0.850	1	-0.853498074223356	-0.099980852529065
365	BR0000012312061	Alchemilla monticola Opiz	A_monticola_52	0.15150080	-0.03519433	0.229	1.151	0.870	0.841	1	-1.112984319972970	0.114126797237043

366	BR0000012594818	Alchemilla monticola Opiz	A_monticola_53	0.06006710	-0.12860690	0.347	1.274	0.785	0.808	1	-0.875723798965745	-1.032178474567590
367	BR0000022438560	Alchemilla monticola Opiz	A_monticola_54	-0.01114612	0.05724396	0.251	1.224	0.817	0.860	1	-0.222019045332969	0.343655122505472
368	BR0000024647564	Alchemilla monticola Opiz	A_monticola_55	0.06780551	-0.00636944	0.304	1.279	0.782	0.814	1	-0.512620518208349	-0.059105137214058
369	BR0000025301946V	Alchemilla monticola Opiz	A_monticola_56	0.05827827	0.01162144	0.259	1.247	0.808	0.806	1	-0.424113781849448	0.137865643671167
370	BR0000025301977V	Alchemilla monticola Opiz	A_monticola_57	0.03089850	0.02878507	0.227	1.245	0.803	0.815	1	-0.278382990685120	0.263305464584970
371	BR0000025301991V	Alchemilla monticola Opiz	A_monticola_58	-0.05536895	-0.07668877	0.205	1.302	0.768	0.736	1	0.454730113179696	-0.433476284090972
372	BR0000025302011V	Alchemilla monticola Opiz	A_monticola_59	0.04519414	0.05357715	0.225	1.167	0.857	0.778	1	-0.356855263498266	0.538513697585080
373	BR0000025302028V	Alchemilla monticola Opiz	A_monticola_60	0.03794399	0.01976605	0.332	1.294	0.779	0.842	1	-0.421245337593421	-0.026914299625444
374	BR0000025302042V	Alchemilla monticola Opiz	A_monticola_61	0.04949277	-0.00208840	0.258	1.254	0.798	0.790	1	-0.383633261829125	0.062057749002817
375	BR0000025302059V	Alchemilla monticola Opiz	A_monticola_62	0.02206977	0.06110775	0.271	1.228	0.823	0.817	1	-0.321838991594718	0.372286910683587
376	BR0000025302066V	Alchemilla monticola Opiz	A_monticola_63	0.07586349	0.00521716	0.345	1.264	0.791	0.854	1	-0.647874458578977	-0.069380485628159
377	BR0000025302110V	Alchemilla monticola Opiz	A_monticola_64	-0.04862311	-0.01414652	0.263	1.318	0.760	0.786	1	0.019862363774325	-0.196884649143638
378	BR0000026172712V	Alchemilla monticola Opiz	A_monticola_65	0.06258977	0.03642820	0.138	2.219	0.560	0.662	2	2.844866441686960	-1.192322010360860
379	BR0000027464106V	Alchemilla monticola Opiz	A_monticola_66	-0.04468888	0.01433117	0.249	1.341	0.748	0.796	1	0.057789702333095	-0.034709902868563
380	BR0000031845236	Alchemilla monticola Opiz	A_monticola_67	0.02309110	-0.00370189	0.285	1.417	0.714	0.807	1	-0.185692946076917	-0.171577984702545
381	BR0000031845250	Alchemilla monticola Opiz	A_monticola_68	0.03822877	0.03971394	0.257	1.273	0.791	0.826	1	-0.323129536253817	0.240088582182437
382	BR0000031845267	Alchemilla monticola Opiz	A_monticola_69	-0.05662561	0.04117306	0.333	1.378	0.728	0.794	1	0.106785800230854	-0.093918422087228
383	BR0000031845274	Alchemilla monticola Opiz	A_monticola_70	0.08730954	0.02605736	0.336	1.235	0.818	0.840	1	-0.682366253194639	0.132605363202168
384	BR0000031845328	Alchemilla monticola Opiz	A_monticola_71	0.20659700	0.04832323	0.245	1.162	0.861	0.853	1	-1.234968662842560	0.664983075402234
385	BR0000031845458	Alchemilla monticola Opiz	A_monticola_72	-0.12289230	-0.03147321	0.366	1.400	0.715	0.833	1	0.165871595674206	-0.802737155145306
386	BR0000031845526	Alchemilla monticola Opiz	A_monticola_73	0.05163317	-0.05340265	0.274	1.317	0.760	0.797	1	-0.482040764588625	-0.339002930447892
387	BR0000031845533	Alchemilla monticola Opiz	A_monticola_74	0.03494872	0.08416573	0.211	1.214	0.824	0.794	1	-0.294149107733979	0.695814203295331
388	BR0000031845540	Alchemilla monticola Opiz	A_monticola_75	0.01447799	-0.05947762	0.451	1.409	0.710	0.857	1	-0.548986290649218	-1.031066232903610
389	E00093043	Alchemilla monticola Opiz	A_monticola_76	0.04281647	-0.04980819	0.291	1.267	0.789	0.793	1	-0.493419582477545	-0.310257352482235
390	E00128233	Alchemilla monticola Opiz	A_monticola_77	0.07697623	-0.04923353	0.219	1.253	0.798	0.816	1	-0.682400846542646	-0.176970039334817
391	E01153213	Alchemilla monticola Opiz	A_monticola_78	0.08346804	-0.04283403	0.303	1.274	0.785	0.856	1	-0.695596304929881	-0.278139816377260
392	E01153214	Alchemilla monticola Opiz	A_monticola_79	0.01140425	-0.01904877	0.201	1.700	0.592	0.656	2	1.067579248693180	-0.170176513379286
393	E01153215	Alchemilla monticola Opiz	A_monticola_80	0.03059649	-0.02987541	0.007	1.609	0.643	0.390	2	2.099475456649600	0.922786123773989
394	E01153216	Alchemilla monticola Opiz	A_monticola_81	0.07883244	-0.00884253	0.272	1.226	0.816	0.823	1	-0.597913712330029	0.027218724103321
395	E01153219	Alchemilla monticola Opiz	A_monticola_82	-0.06933036	0.02326764	0.308	1.276	0.784	0.804	1	0.030056631674360	-0.091853102838046
396	E01153220	Alchemilla monticola Opiz	A_monticola_83	0.18304390	-0.04199831	0.320	1.166	0.858	0.832	1	-1.289954191462260	-0.069207006943067
397	E01153221	Alchemilla monticola Opiz	A_monticola_84	0.08647702	-0.07897945	0.262	1.219	0.821	0.858	1	-0.893453372082396	-0.435511564570699
398	E01153222	Alchemilla monticola Opiz	A_monticola_85	0.25001460	-0.09136389	0.291	1.214	0.823	0.840	1	-1.802769148584840	-0.299412700700694
399	E01153223	Alchemilla monticola Opiz	A_monticola_86	0.05622114	-0.10952350	0.422	1.332	0.751	0.850	1	-0.844730647015822	-1.119577542801470
400	E01153224	Alchemilla monticola Opiz	A_monticola_87	-0.05304736	-0.01751917	0.055	1.112	0.899	0.357	2	1.316731115055820	1.630325546009300
401	E01153225	Alchemilla monticola Opiz	A_monticola_88	-0.03787846	0.03127548	0.303	1.104	0.906	0.387	2	0.349100504643843	1.463204454429880
402	E01153228	Alchemilla monticola Opiz	A_monticola_89	0.07886076	0.05489500	0.162	2.086	0.564	0.597	2	2.557802908735400	-0.704434535172788
403	E01153229	Alchemilla monticola Opiz	A_monticola_90	-0.00462873	-0.08990039	0.230	1.770	0.587	0.566	2	1.541701547488300	-0.786816767223307
404	E01153232	Alchemilla monticola Opiz	A_monticola_91	-0.00972871	-0.02573698	0.200	1.265	0.792	0.794	1	-0.047278264552478	0.027418705062299
405	E01153299	Alchemilla monticola Opiz	A_monticola_92	0.02406651	-0.00426272	0.012	1.228	0.814	0.459	2	1.114027532900770	1.463507229946890
406	UGDA.0023974	Alchemilla monticola Opiz	A_monticola_93	0.02886871	0.02939879	0.215	1.209	0.828	0.813	1	-0.284226377889035	0.336001762069014
407	UGDA.0023982	Alchemilla monticola Opiz	A_monticola_94	0.11063040	-0.05835269	0.231	1.201	0.833	0.792	1	-0.924451475288197	-0.137544357031062
408	UGDA.0033311	Alchemilla monticola Opiz	A_monticola_95	-0.11833120	0.05365467	0.082	1.395	0.717	0.764	1	0.958891195798534	0.430444309035970
409	UGDA.0040925	Alchemilla monticola Opiz	A_monticola_96	0.05271715	0.05994188	0.293	1.252	0.799	0.858	1	-0.494262063549289	0.340006289124035
410	UGDA.0040927	Alchemilla monticola Opiz	A_monticola_97	-0.05648260	0.07123807	0.293	1.274	0.785	0.801	1	0.038591672738167	0.288342111327485
411	UGDA.0093434	Alchemilla monticola Opiz	A_monticola_98	0.12446360	0.03129702	0.310	1.223	0.818	0.810	1	-0.782763255115448	0.286100064960781
412	UGDA.0093435	Alchemilla monticola Opiz	A_monticola_99	0.10699650	-0.03483868	0.158	1.244	0.805	0.700	1	-0.115351571342069	0.774036119878411
413	UGDA.0114796	Alchemilla monticola Opiz	A_monticola_100	0.14199730	-0.00439315	0.283	1.217	0.822	0.862	1	-0.931715147587692	0.101749755261883
414	UGDA.0140624	Alchemilla monticola Opiz	A_monticola_101	0.03995665	0.00534875	0.336	1.339	0.751	0.824	1	-0.386969363822614	-0.140618111214132
415	UGDA.0040926	Alchemilla obtusa Buser	A_obtusa_1	0.00282905	0.10841980	0.322	1.310	0.763	0.825	1	-0.373582933082759	0.689106675626216
416	UGDA.0033737	Alchemilla pastoralis Buser	A_pastoralis_1	0.01050943	-0.01070000	0.274	1.252	0.799	0.822	1	-0.304629022802814	-0.091411670280657
417	UGDA.0040839	Alchemilla pastoralis Buser	A_pastoralis_2	-0.02299914	0.06103802	0.204	1.284	0.783	0.793	1	0.031192322428420	0.417955831063646
418	UGDA.0143251	Alchemilla pastoralis Buser	A_pastoralis_3	-0.09188665	0.03319814	0.278	1.366	0.732	0.797	1	0.246637792183034	-0.099599357214481
419	UGDA.0201600	Alchemilla pastoralis Buser	A_pastoralis_4	-0.09125576	-0.04615762	0.272	1.280	0.781	0.804	1	0.098964827816986	-0.508693533768009
420	UGDA.0237565	Alchemilla pastoralis Buser	A_pastoralis_5	-0.33536450	-0.12631420	0.173	1.505	0.664	0.828	1	1.513304823787440	-2.050076401930210
421	UGDA.0237575	Alchemilla pastoralis Buser	A_pastoralis_6	0.10785930	-0.03388170	0.358	1.299	0.770	0.854	1	-0.835030104627317	-0.317441139876827
422	UGDA.0237583	Alchemilla pastoralis Buser	A_pastoralis_7	0.12622910	-0.00822201	0.271	1.232	0.812	0.854	1	-0.833494287007278	0.072781232529576
423	L.1889090	Alchemilla plicata Buser	A_plicata_1	0.04558252	0.00918344	0.245	1.299	0.770	0.834	1	-0.344343903340375	0.079128179430006
424	L.1889097	Alchemilla plicata Buser	A_plicata_2	-0.04173113	-0.00429301	0.295	1.338	0.749	0.816	1	-0.052249803108828	-0.228255873364386
425	L.1889096	Alchemilla plicata Buser	A_plicata_3	-0.00891018	-0.05054103	0.290	1.326	0.755	0.842	1	-0.258790181906889	-0.451922408647060
426	L.1889095	Alchemilla plicata Buser	A_plicata_4	-0.01146374	-0.01475868	0.268	1.381	0.726	0.818	1	-0.100138899324441	-0.226561381673523
427	L.1889093	Alchemilla plicata Buser	A_plicata_5	-0.09985905	-0.02794327	0.290	1.493	0.671	0.822	1	0.301602682627085	-0.606552259509897

428	L.4208039	Alchemilla plicata Buser	A_plicata_6	0.05982975	0.02696092	0.291	1.288	0.777	0.840	1	-0.451815281468109	0.120292467660754
429	323136	Alchemilla plicata Buser	A_plicata_7	-0.08901453	0.05548273	0.127	1.378	0.729	0.681	1	0.725380120959842	0.497797708610353
430	323137	Alchemilla plicata Buser	A_plicata_8	-0.07450288	-0.02158162	0.232	1.432	0.699	0.832	1	0.258291147837649	-0.366561007681317
431	323138	Alchemilla plicata Buser	A_plicata_9	-0.14384320	-0.05701051	0.258	1.455	0.693	0.714	1	0.671475336387303	-0.650367023111257
432	323140	Alchemilla plicata Buser	A_plicata_10	-0.14844740	-0.03467138	0.282	1.553	0.644	0.853	1	0.552096878687633	-0.865933092011380
433	323141	Alchemilla plicata Buser	A_plicata_11	-0.06873289	-0.04385809	0.301	1.467	0.685	0.847	1	0.099904615646573	-0.657005184915221
434	323143	Alchemilla plicata Buser	A_plicata_12	-0.06223181	-0.02805636	0.314	1.336	0.749	0.862	1	-0.065065533189169	-0.474670819571175
435	323144	Alchemilla plicata Buser	A_plicata_13	0.00903743	-0.06087576	0.299	1.386	0.722	0.844	1	-0.298348491331833	-0.562418177760155
436	323145	Alchemilla plicata Buser	A_plicata_14	-0.01173183	-0.05576346	0.263	1.390	0.726	0.846	1	-0.169141879060112	-0.525141728366475
437	323146	Alchemilla plicata Buser	A_plicata_15	-0.06590128	-0.05707431	0.330	1.458	0.686	0.857	1	0.018617725382123	-0.787853996637176
438	323147	Alchemilla plicata Buser	A_plicata_16	-0.18817000	-0.02339404	0.224	1.532	0.653	0.828	1	0.838000363946584	-0.771933079354115
439	323148	Alchemilla plicata Buser	A_plicata_17	-0.01883754	-0.02208103	0.234	1.404	0.714	0.818	1	0.021685175089262	-0.244188836649958
440	323415	Alchemilla plicata Buser	A_plicata_18	-0.10216510	-0.03718288	0.337	1.480	0.676	0.855	1	0.185647439339312	-0.784604504936763
441	328339	Alchemilla plicata Buser	A_plicata_19	-0.07512944	0.03507178	0.007	1.524	0.656	0.305	2	2.171462095732040	1.268223174002430
442	336488	Alchemilla plicata Buser	A_plicata_20	-0.08849581	-0.00723251	0.286	1.453	0.690	0.836	1	0.224830973861982	-0.439322187678956
443	60989	Alchemilla plicata Buser	A_plicata_21	-0.01843244	0.01194021	0.199	1.301	0.769	0.802	1	0.019448104343201	0.156296477304174
444	61029	Alchemilla plicata Buser	A_plicata_22	0.06246003	0.03224058	0.204	1.280	0.785	0.810	1	-0.317888782005868	0.382318035648754
445	61986	Alchemilla plicata Buser	A_plicata_23	-0.00313521	0.02415390	0.278	1.383	0.723	0.866	1	-0.138280386273949	-0.054476523863151
446	61987	Alchemilla plicata Buser	A_plicata_24	0.00460331	0.09222682	0.204	1.221	0.819	0.817	1	-0.216202833970171	0.731752277141752
447	61995	Alchemilla plicata Buser	A_plicata_25	-0.09692184	-0.04480039	0.003	1.518	0.659	0.405	2	2.135427630116380	0.715055010245270
448	62011	Alchemilla plicata Buser	A_plicata_26	-0.00753251	0.06582824	0.164	1.373	0.729	0.819	1	0.164210765682360	0.515853282460067
449	62020	Alchemilla plicata Buser	A_plicata_27	-0.15468620	0.04102178	0.008	2.356	0.425	0.279	2	6.256380261470670	0.248057679152533
450	WAG.1503792	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_1	0.16846880	0.04502275	0.370	1.247	0.802	0.891	1	-1.246388204854750	0.287968163237672
451	L.1889102	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_2	-0.03061481	-0.05187807	0.337	1.388	0.722	0.853	1	-0.172378981062466	-0.632725913711056
452	323512	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_3	-0.01050671	-0.11851870	0.270	1.197	0.835	0.347	2	1.862587272548730	-0.009363393648200
453	323514	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_4	0.07491846	0.00360473	0.051	1.044	0.958	0.345	2	0.737734809372271	2.165246842806850
454	323515	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_5	0.05875870	0.02131672	0.256	1.108	0.904	0.328	2	0.245352974613887	1.801168583490920
455	60970	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_6	0.06239836	0.07630865	0.162	1.224	0.826	0.463	2	0.309731856708113	1.442726051803660
456	62090	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_7	0.09512915	-0.00988346	0.252	1.286	0.779	0.854	1	-0.640524292562640	0.013427437649939
457	62127	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_8	-0.00274753	-0.07802754	0.053	1.058	0.946	0.331	2	1.385208923596690	1.930057246512010
458	62172	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_9	0.02772298	0.01373056	0.262	1.185	0.850	0.667	1	-0.140341022960339	0.410267639282177
459	62336	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_10	0.04298788	0.00729873	0.327	1.296	0.773	0.861	1	-0.460565324347098	-0.099144369975799
460	62339	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_11	0.16937390	-0.00209212	0.227	1.172	0.853	0.857	1	-1.089567579706640	0.318172073907177
461	62352	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_12	0.06465765	0.02872548	0.307	1.318	0.759	0.831	1	-0.460319212033773	0.101528799814484
462	62364	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_13	0.07718753	-0.09222161	0.005	1.314	0.761	0.462	2	1.582058160622520	1.383417927054110
463	E01153170	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_14	0.01565398	0.06256488	0.224	1.249	0.800	0.820	1	-0.218037576586901	0.446502924478528
464	UGDA.0142522	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_15	0.04838967	0.06637227	0.061	1.101	0.908	0.379	2	0.649520605397359	2.046337295377080
465	UGDA.0237584	Alchemilla propinqua H.Lindb. ex Juz.	A_propinqua_16	0.11687640	-0.09417666	0.373	1.259	0.795	0.849	1	-1.100231276696970	-0.716324070973923
466	UGDA.0031237	Alchemilla sp.	A_sp_1	0.03961422	-0.00839661	0.359	1.253	0.798	0.801	1	-0.506518824320776	-0.189375956021170
467	UGDA.0064213	Alchemilla sp.	A_sp_2	-0.02909800	-0.03535180	0.258	1.393	0.718	0.838	1	-0.044991250987450	-0.390623235490968
468	UGDA.0087204	Alchemilla sp.	A_sp_3	-0.12553640	-0.04555542	0.292	1.474	0.679	0.869	1	0.317513005874622	-0.815444983158349
469	UGDA.0097304	Alchemilla sp.	A_sp_4	-0.04522998	-0.04061252	0.278	1.340	0.746	0.801	1	-0.036107419144259	-0.401761102512375
470	UGDA.0098982	Alchemilla sp.	A_sp_5	0.06483239	-0.10817140	0.242	1.229	0.814	0.786	1	-0.875446892703566	-0.702284499052829
471	UGDA.0098985	Alchemilla sp.	A_sp_6	0.12503930	0.08154343	0.335	1.248	0.801	0.843	1	-0.907464056932380	0.588044940563025
472	UGDA.0109002	Alchemilla sp.	A_sp_7	0.06771620	0.01263493	0.306	1.287	0.777	0.845	1	-0.516226049888423	0.021197903837660
473	UGDA.0109005	Alchemilla sp.	A_sp_8	0.06771164	-0.11204370	0.041	2.695	0.371	0.371	2	7.895346482633080	-1.803763249881840
474	UGDA.0109016	Alchemilla sp.	A_sp_9	-0.03264801	0.07201575	0.329	1.172	0.853	0.880	1	-0.441549792572326	0.471460701723748
475	UGDA.0109019	Alchemilla sp.	A_sp_10	0.01992116	0.07361382	0.348	1.266	0.790	0.858	1	-0.499297531313025	0.375061698770998
476	UGDA.0114795	Alchemilla sp.	A_sp_11	-0.00788218	0.05778960	0.404	1.397	0.716	0.815	1	-0.159076062022989	0.004719086310817
477	UGDA.0114797	Alchemilla sp.	A_sp_12	0.10276630	-0.03380384	0.254	1.251	0.799	0.862	1	-0.778075304188414	-0.106618731043648
478	UGDA.0114801	Alchemilla sp.	A_sp_13	-0.06065380	0.01577808	0.320	1.344	0.744	0.847	1	0.001944215882110	-0.237277374564206
479	UGDA.0114802	Alchemilla sp.	A_sp_14	-0.04312714	0.06116451	0.366	1.403	0.713	0.827	1	0.140293404557639	-0.015456924907136
480	UGDA.0114823	Alchemilla sp.	A_sp_15	-0.00926961	-0.01509652	0.340	1.345	0.745	0.816	1	-0.220073455034464	-0.329038448630258
481	UGDA.0114824	Alchemilla sp.	A_sp_16	-0.01747107	0.07675878	0.299	1.360	0.735	0.843	1	-0.066573645992888	0.298438781848585
482	UGDA.0114826	Alchemilla sp.	A_sp_17	0.09344819	-0.10775340	0.186	1.143	0.875	0.806	1	-1.246375029880240	-0.584068315712926
483	UGDA.0114913	Alchemilla sp.	A_sp_18	0.04879545	0.01534590	0.317	1.287	0.781	0.829	1	-0.436436357602631	0.001626376149845
484	UGDA.0141940	Alchemilla sp.	A_sp_19	-0.14621590	0.03220026	0.438	1.416	0.706	0.851	1	0.268002085551811	-1.133987986792230
485	UGDA.0173451	Alchemilla sp.	A_sp_20	0.02525083	0.00612711	0.219	1.377	0.726	0.805	1	-0.105435386919051	0.087347776511983
486	UGDA.0215379	Alchemilla sp.	A_sp_21	-0.16919790	-0.07048602	0.249	1.616	0.619	0.827	1	0.833279095483820	-1.103016977703200
487	UGDA.0240211	Alchemilla sp.	A_sp_22	-0.13612100	-0.12389210	0.308	1.442	0.694	0.826	1	0.324373769732823	-1.388126915981430
488	UGDA.0240217	Alchemilla sp.	A_sp_23	-0.09844363	0.07092078	0.191	1.304	0.767	0.779	1	0.426171305224184	0.390852603922216
489	WAG.1503812	Alchemilla subcrenata Buser	A_subcrenata_1	0.16085020	0.00611573	0.325	1.217	0.822	0.906	1	-1.126037490811010	0.091868719026029

490	L.1888231	Alchemilla subcrenata Buser	A_subcrenata_2	-0.01340931	0.09645724	0.268	1.278	0.782	0.837	1	-0.195426867799265	0.584912470835552
491	L.1888237	Alchemilla subcrenata Buser	A_subcrenata_3	0.12081650	-0.05216696	0.254	1.258	0.799	0.851	1	-0.904698830692342	-0.203442109600258
492	L.1888234	Alchemilla subcrenata Buser	A_subcrenata_4	0.15606020	0.01543432	0.294	1.179	0.848	0.838	1	-0.994712562082142	0.268390170258276
493	L.1888235	Alchemilla subcrenata Buser	A_subcrenata_5	0.01182175	-0.01116636	0.314	1.384	0.723	0.822	1	-0.231528811338626	-0.262368419638148
494	L.1888240	Alchemilla subcrenata Buser	A_subcrenata_6	0.04643831	0.00428845	0.207	1.354	0.746	0.679	1	0.097329920203809	0.372667170080960
495	L.3249894	Alchemilla subcrenata Buser	A_subcrenata_7	0.11201120	-0.01172388	0.234	1.182	0.846	0.801	1	-0.772319961400428	0.192231782452772
496	L.3249895	Alchemilla subcrenata Buser	A_subcrenata_8	0.09465037	-0.02462550	0.277	1.186	0.843	0.773	1	-0.723976922831747	0.021979554017352
497	L.3249889	Alchemilla subcrenata Buser	A_subcrenata_9	0.14395700	0.01299817	0.136	1.159	0.864	0.678	1	-0.376112708837178	1.112183155513200
498	L.3249888	Alchemilla subcrenata Buser	A_subcrenata_10	0.02641651	0.21730180	0.348	1.161	0.861	0.851	1	-1.613011320804460	1.663032828040190
499	U.1542452	Alchemilla subcrenata Buser	A_subcrenata_11	0.06312643	0.02446710	0.313	1.333	0.751	0.835	1	-0.454200992249374	0.050952759580705
500	U.1542453	Alchemilla subcrenata Buser	A_subcrenata_12	0.12334730	-0.05827209	0.279	1.288	0.778	0.859	1	-0.915404838335898	-0.307932638169381
501	L.3962790	Alchemilla subcrenata Buser	A_subcrenata_13	0.01000355	-0.04191006	0.368	1.367	0.733	0.825	1	-0.354113882109739	-0.547302272538246
502	E00128235	Alchemilla subcrenata Buser	A_subcrenata_14	-0.02487430	-0.03032728	0.317	1.302	0.768	0.773	1	-0.155974450505378	-0.334926416447870
503	E00800254	Alchemilla subcrenata Buser	A_subcrenata_15	0.16939830	-0.03153135	0.308	1.205	0.832	0.834	1	-1.133495944031480	-0.033336009285395
504	E01153327	Alchemilla subcrenata Buser	A_subcrenata_16	0.16851190	0.08115324	0.297	1.134	0.882	0.378	2	-0.475089523984191	2.037104796119520
505	E01153328	Alchemilla subcrenata Buser	A_subcrenata_17	0.04386346	0.00915336	0.257	1.276	0.784	0.798	1	-0.329977883513225	0.093875330667659
506	E01153329	Alchemilla subcrenata Buser	A_subcrenata_18	-0.00120973	0.17224600	0.368	1.242	0.805	0.886	1	-1.209232575960940	1.285808298474820
507	E01153330	Alchemilla subcrenata Buser	A_subcrenata_19	0.16488410	-0.05824556	0.250	1.269	0.788	0.820	1	-1.125342913629460	-0.162094680253562
508	E01153333	Alchemilla subcrenata Buser	A_subcrenata_20	0.04646405	0.14854550	0.004	1.347	0.743	0.417	2	0.890167392524937	2.436946458547030
509	E01153335	Alchemilla subcrenata Buser	A_subcrenata_21	0.07977131	-0.06629729	0.374	1.330	0.755	0.815	1	-0.743057354441017	-0.606948303022030
510	E01153336	Alchemilla subcrenata Buser	A_subcrenata_22	0.07615630	-0.09141678	0.242	1.297	0.771	0.775	1	-0.765810210167105	-0.569583597402277
511	UGDA.0099046	Alchemilla vulgaris L.	A_vulgaris_1	0.05218719	-0.00389678	0.301	1.259	0.794	0.830	1	-0.478387417220398	-0.057747300469639
512	UGDA.0128572	Alchemilla vulgaris L.	A_vulgaris_2	-0.05371839	0.07324986	0.073	1.181	0.847	0.406	2	0.998139020229723	1.662893225359770
513	UGDA.0139632	Alchemilla vulgaris L.	A_vulgaris_3	-0.00092332	0.04062227	0.346	1.124	0.890	0.441	2	0.026350028488195	1.330941505806530
514	UGDA.0180955	Alchemilla vulgaris L.	A_vulgaris_4	0.04391297	0.06081021	0.369	1.228	0.815	0.844	1	-0.641921435382280	0.324023874145732

Supplementary Table S4. Pairwise PERMANOVA results for comparisons among the analysed *Alchemilla* taxa.

Supplementary Table S4. Pairwise PERMANOVA results for comparisons among the analysed *Alchemilla* taxa.

No.	Group 1	Group 2	n1	n2	F	R^2	p	Adjusted p*
1	*Alchemilla monticola* Opiz	*Alchemilla plicata* Buser	101	27	11.9553	0.0867	0.0001	0.0007
2	*Alchemilla plicata* Buser	*Alchemilla propinqua* H.Lindb. ex Juz.	27	16	10.6346	0.2060	0.0001	0.0007
3	*Alchemilla plicata* Buser	*Alchemilla subcrenata* Buser	27	22	9.2306	0.1642	0.0001	0.0007
4	*Alchemilla glabra* Neygenf.	*Alchemilla monticola* Opiz	238	101	9.8019	0.0283	0.0002	0.0008
5	*Alchemilla glabra* Neygenf.	*Alchemilla propinqua* H.Lindb. ex Juz.	238	16	12.9408	0.0488	0.0002	0.0008
6	*Alchemilla mollis* (Buser) Rothm.	*Alchemilla plicata* Buser	20	27	7.4204	0.1416	0.0004	0.0014
7	*Alchemilla monticola* Opiz	*Alchemilla propinqua* H.Lindb. ex Juz.	101	16	7.1183	0.0583	0.0014	0.0042
8	*Alchemilla glabra* Neygenf.	*Alchemilla glaucescens* Wallr.	238	52	5.1781	0.0177	0.0056	0.0147
9	*Alchemilla glabra* Neygenf.	*Alchemilla plicata* Buser	238	27	5.3632	0.0200	0.0070	0.0163
10	*Alchemilla glabra* Neygenf.	*Alchemilla subcrenata* Buser	238	22	4.5503	0.0173	0.0110	0.0231
11	*Alchemilla glabra* Neygenf.	*Alchemilla mollis* (Buser) Rothm.	238	20	4.1624	0.0160	0.0145	0.0277
12	*Alchemilla propinqua* H.Lindb. ex Juz.	*Alchemilla subcrenata* Buser	16	22	3.9961	0.0999	0.0279	0.0488
13	*Alchemilla mollis* (Buser) Rothm.	*Alchemilla propinqua* H.Lindb. ex Juz.	20	16	3.5648	0.0949	0.0388	0.0627
14	*Alchemilla glaucescens* Wallr.	*Alchemilla propinqua* H.Lindb. ex Juz.	52	16	3.0158	0.0437	0.0463	0.0695
15	*Alchemilla glaucescens* Wallr.	*Alchemilla plicata* Buser	52	27	2.9353	0.0367	0.0661	0.0925
16	*Alchemilla glaucescens* Wallr.	*Alchemilla mollis* (Buser) Rothm.	52	20	2.4277	0.0335	0.0809	0.1062
17	*Alchemilla glaucescens* Wallr.	*Alchemilla monticola* Opiz	52	101	2.0248	0.0132	0.1235	0.1475
18	*Alchemilla mollis* (Buser) Rothm.	*Alchemilla monticola* Opiz	20	101	1.9460	0.0161	0.1264	0.1475
19	*Alchemilla glaucescens* Wallr.	*Alchemilla subcrenata* Buser	52	22	1.5572	0.0212	0.1955	0.2161
20	*Alchemilla mollis* (Buser) Rothm.	*Alchemilla subcrenata* Buser	20	22	0.5633	0.0139	0.6055	0.6279
21	*Alchemilla monticola* Opiz	*Alchemilla subcrenata* Buser	101	22	0.5312	0.0044	0.6279	0.6279

**Adjusted p-values correspond to the Benjamini–Hochberg correction. Values are shown to four decimal places; n1 and n2 indicate sample sizes for Group 1 and Group 2, respectively.*

Supplementary Table S5. Distribution of the analysed *Alchemilla* taxa and unidentified *Alchemilla* sp. specimens between the two phenotypic clusters identified by hierarchical clustering.

Supplementary Table S5. Distribution of the analysed *Alchemilla* taxa and unidentified *Alchemilla* sp. specimens between the two phenotypic clusters identified by hierarchical clustering.

Taxon	Total specimens (n)	Cluster 1 (n)	Cluster 1 (%)	Cluster 2 (n)	Cluster 2 (%)
Alchemilla acutiloba Opiz	2	2	100.00	0	0.00
Alchemilla glabra Neygenf.	238	209	87.82	29	12.18
Alchemilla glaucescens Wallr.	52	45	86.54	7	13.46
Alchemilla hybrida (L.) L.	1	1	100.00	0	0.00
Alchemilla mollis (Buser) Rothm.	20	15	75.00	5	25.00
Alchemilla monticola Opiz	101	89	88.12	12	11.88
Alchemilla obtusa Buser	1	1	100.00	0	0.00
Alchemilla pastoralis Buser	7	7	100.00	0	0.00
Alchemilla plicata Buser	27	24	88.89	3	11.11
Alchemilla propinqua H.Lindb. ex Juz.	16	9	56.25	7	43.75
Alchemilla sp.	23	22	95.65	1	4.35
Alchemilla subcrenata Buser	22	20	90.91	2	9.09
Alchemilla vulgaris L.	4	2	50.00	2	50.00

**Percentages are calculated within each taxon. Cluster assignments are based on specimen-level mean morphometric values.*

12. Oświadczenia kandydata

Pragnę poświadczyć, iż zamieszczone poniżej oświadczenia, podpisane przez współautorów oraz przeze mnie, zachowują ważność. Oświadczenia dotyczące dwóch manuskryptów pt. „Limited congruence between leaf micromorphology and molecular differentiation in selected *Alchemilla* L. species" oraz „Leaf morphometry of selected species of the genus *Alchemilla* L. (Rosaceae) from Europe" zostały podpisane przed zmianą tytułów manuskryptów oraz ich skierowaniem do czasopism. Aktualne tytuły manuskryptów brzmią odpowiednio: „Leaf character variation does not consistently track molecular differentiation in selected *Alchemilla* L. species" oraz „Can leaf morphometry support species identification in *Alchemilla*? Evidence from digitised European herbarium specimens". Zmiany dotyczyły wyłącznie tytułów manuskryptów i nie wpłynęły na ich autorstwo ani zakres wkładu poszczególnych współautorów.

mgr Adrianna Maria Kosiróg-Ceynowa
Katedra Taksonomii Roślin
i Ochrony Przyrody
Wydział Biologii, Uniwersytet Gdański
ul. Wita Stwosza 59, 80-308 Gdańsk

Gdańsk, 24.09.2026 r.

Oświadczam, że mój indywidualny wkład autorski w powstanie artykułu naukowego

„Limited taxonomic value of achene shape but diagnostic potential of micromorphology in selected Polish taxa of Alchemilla L. (Rosaceae)"

obejmował:

- udział w opracowaniu koncepcji i projektu badań,
- udział w opracowaniu metodyki badań,
- zapewnienie i zgromadzenie materiałów oraz zasobów niezbędnych do realizacji badań,
- pozyskanie, opracowanie i upor. ądkowanie danych,
- udział w interpretacji uzyskanych wyników,
- przygotowanie pierwotnej wersji manuskryptu,
- udział w krytycznym przeglądzie, redakcji i przygotowaniu ostatecznej wersji manuskryptu,
- przygotowanie wizualizacji wyników,
- udział w zarządzaniu i koordynacji realizacji projektu,
- konsultacje merytoryczne ze współautorami.

Adrianna Maria Kosiróg-Ceynowa

Podpis

mgr Adrianna Maria Kosiróg-Ceynowa
Katedra Taksonomii Roślin
i Ochrony Przyrody
Wydział Biologii, Uniwersytet Gdański
ul. Wita Stwosza 59, 80-308 Gdańsk

Gdańsk, 24.09.2026 r.

Oświadczam, że mój indywidualny wkład autorski w powstanie artykułu naukowego

„Limited congruence between leaf micromorphology and molecular differentiation in selected Alchemilla L. species"

obejmował:

- udział w opracowaniu koncepcji pracy,
- udział w opracowaniu metodyki badan,
- zapewnienie i zgromadzenie materiałów oraz zasobów niezbędnych do realizacji badań,
- opracowanie i uporządkowanie danych,
- przygotowanie pierwotnej wersji manuskryptu,
- udział w przeglądzie, redakcji i przygotowaniu ostatecznej wersji manuskryptu,
- przygotowanie wizualizacji wyników,
- udział w zarządzaniu i koordynacji realizacji projektu,
- konsultacje ze współautorami.

Adrianna Maria Kosiróg-Ceynowa

Podpis

mgr Adrianna Maria Kosiróg-Ceynowa
Katedra Taksonomii Roślin
i Ochrony Przyrody
Wydział Biologii, Uniwersytet Gdański
ul. Wita Stwosza 59, 80-308 Gdańsk

Gdańsk, 24.09.2026 r.

Oświadczam, że mój indywidualny wkład autorski w powstanie artykułu naukowego

„Leaf morphometry of selected species of the genus Alchemilla L. (Rosaceae) from Europe"

obejmował:

- udział w opracowaniu koncepcji pracy,
- udział w opracowaniu metodyki badań,
- zapewnienie i zgromadzenie materiałów oraz zasobów niezbędnych do realizacji badań,
- pozyskanie, opracowanie i uporządkowanie danych,
- udział w interpretacji uzyskanych wyników,
- przygotowanie pierwotnej wersji manuskryptu,
- udział w przeglądzie, redakcji i przygotowaniu ostatecznej wersji manuskryptu,
- przygotowanie wizualizacji wyników,
- udział w zarządzaniu i koordynacji realizacji projektu,
- konsultacje ze współautorami.

Adrianna Maria Kosiróg-Ceynowa

Podpis

13. Oświadczenia współautorów

Gdańsk, 11.09.2026r.

mgr Julia Jaskólska
Pracownia Lichenologii i Mykologii Eksperymentalnej,
Katedra Taksonomii Roślin i Ochrony Przyrody,
Uniwersytet Gdański, ul. Wita Stwosza 59, 80-308 Gdańsk

Oświadczenie o wkładzie w publikację

Oświadczam, że mój indywidualny wkład autorski w powstanie artykułu naukowego: *„Limited taxonomic value of achene shape but diagnostic potential of micromorphology in selected Polish taxa of Alchemilla L. (Rosaceae)"*

obejmował:

- udział w opracowaniu koncepcji i projektu badan,
- udział w interpretacji uzyskanych wyników,
- udział w krytycznym przeglądzie, redakcji i korekcie kolejnych wersji manuskryptu.

Julia Jaskólska

.....
Podpis współautorki

dr hab. Agnieszka Rewicz, prof. UŁ
Katedra Geobotaniki i Ekologii Roślin,
Wydział Biologii i Ochrony Środowiska,
Uniwersytet Łódzki,
ul. Banacha 12/16, 90-237 Łódź

Łódź, 11.09.2026 r.

Oświadczam, że mój indywidualny wkład autorski w powstanie artykułu naukowego

„Limited taxonomic value of achene shape but diagnostic potential of micromorphology in selected Polish taxa of Alchemilla L. (Rosaceae)"

obejmował:

- udział w zgromadzeniu materiału badawczego i pozyskiwaniu danych,
- udział w opracowaniu koncepcji i projektu badań,
- udział w interpretacji uzyskanych wyników,
- udział w krytycznym przeglądzie, redakcji i korekcie kolejnych wersji manuskryptu.

Agnieszka Rewicz

.....

Podpis współautora

prof. dr hab. Dariusz L. Szlachetko
Katedra Taksonomii Roślin
i Ochrony Przyrody
Wydział Biologii, Uniwersytet Gdański
ul. Wita Stwosza 59, 80-308 Gdańsk

Gdańsk, 22.09.2026 r.

Oświadczam, że mój indywidualny wkład autorski w powstanie artykułu naukowego

„Limited taxonomic value of achene shape but diagnostic potential of micromorphology in selected Polish taxa of Alchemilla L. (Rosa eae)"

obejmował:

- nadzór merytoryczny nad realizacją badań,
- akceptacja ostatecznej wersji manuskryptu.

.....

Podpis współautora

dr Sławomir Nowak
Katedra Taksonomii Roślin
i Ochrony Przyrody
Wydział Biologii, Uniwersytet Gdański
ul. Wita Stwosza 59, 80-308 Gdańsk

Gdańsk, 11.09.2026 r.

Oświadczam, że mój indywidualny wkład autorski w powstanie artykułu naukowego

„Limited taxonomic value of achene shape but diagnostic potential of micromorphology in selected Polish taxa of Alchemilla L. (Rosaceae)"

obejmował:

- udział w opracowaniu koncepcji i projektu badań,
- udział w interpretacji uzyskanych wyników,
- udział w krytycznym przeglądzie, redakcji i korekcie kolejnych wersji manuskryptu,
- nadzór merytoryczny nad realizacją badań.

Sławomir Nowak

Podpis współautora

dr Magdalena Dudek,
Katedra Taksonomii Roślin
i Ochrony Przyrody
Wydział Biologii, Uniwersytet Gdański
ul. Wita Stwosza 59, 80-308 Gdańsk

Gdańsk, 22.09.2026 r.

Oświadczam, że mój indywidualny wkład autorski w powstanie artykułu naukowego

„Limited congruence between leaf micromorphology and molecular differentiation in selected Alchemilla L. species"

obejmował:

- udział merytoryczny w pozyskiwaniu danych,
- współudział w opracowaniu koncepcji pracy,
- udział w interpretacji uzyskanych danych,
- udział w przygotowaniu manuskryptu,
- udział w redakcji i korekcie kolejnych wersji manuskryptu.

Magdalena Dudek

Podpis współautora

POLITECHNIKA
BYDGOSKA
Wydział Rolnictwa i Biotechnologii
KATEDRA BIOTECHNOLOGII

HR EXCELLENCE IN RESEARCH

Bydgoszcz, 16 września 2026

dr hab. inż. Iwona Jędrzejczyk, prof. PBŚ
Katedra Biotechnologii
Wydział Rolnictwa i Biotechnologii
Politechnika Bydgoska im. J. i J. Śniadeckich
Aleje prof. S. Kaliskiego 7, 85-796 Bydgoszcz

Oświadczam, że mój indywidualny wkład autorski w powstanie artykułu naukowego:

„Limited congruence between leaf micromorphology and molecular differentiation in selected Alchemilla L. species"

obejmował:

- wykonanie analiz metodą cytometrii przepływowej oraz oszacowanie wielkości genomu,
- udział w przygotowaniu manuskryptu,
- udział w redakcji i korekcie kolejnych wersji manuskryptu.

Kierownik
Katedry Biotechnologii

.....
Podpis współautora

Al. Prof. S. Kaliskiego 7, 85-796 Bydgoszcz
tel. +48 52 340 80 19
e-mail: jedrzej@pbs.edu.pl

Gdańsk, 11.09.2026r.

mgr Julia Jaskólska
Pracownia Lichenologii i Mykologii Eksperymentalnej,
Katedra Taksonomii Roślin i Ochrony Przyrody,
Uniwersytet Gdański, ul. Wita Stwosza 59, 80-308 Gdańsk

Oświadczenie o wkładzie w publikację

Oświadczam, że mój indywidualny wkład autorski w powstanie artykułu naukowego: *„Limited congruence between leaf micromorphology and molecular differentiation in selected Alchemilla L. species"*

obejmował:

- udział w pozyskiwaniu danych,
- współudział w opracowaniu koncepcji pracy,
- udział w interpretacji uzyskanych danych,
- udział w przygotowaniu manuskryptu,
- udział w redakcji i korekcie kolejnych wersji manuskryptu.

Julia Jaskólska
.....
Podpis współautorki

mgr Dorota Łuszczek
Laboratorium Bioobrazowania,
Wydział Biologii, Uniwersytet Gdański,
ul. Wita Stwosza 59, 80-308 Gdańsk

Gdańsk, 11.09.2026 r.

Oświadczam, że mój indywidualny wkład autorski w powstanie artykułu naukowego

„Limited congruence between leaf micromorphology and molecular differentiation in selected Alchemilla L. species"

obejmował:

- udział w opracowaniu i zastosowaniu metodyki badawczej,
- przeprowadzenie badan w tym wykonanie zdjęć sktruktur mikromorfologicznych przy użyciu SEM,
- udział w redakcji i korekcie manuskryptu.

Dorota Łuszczek

Podpis współautora

dr hab. Magdalena Narajczyk, prof. UG
Laboratorium Bioobrazowania,
Wydział Biologii, Uniwersytet Gdański,
ul. Wita Stwosza 59, 80-308 Gdańsk

Gdańsk, 11.09.2026 r.

Oświadczam, że mój indywidualny wkład autorski w powstanie artykułu naukowego

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- udział w redakcji i korekcie manuskryptu.

Magdalena Narajczyk

Podpis współautora

dr Sławomir Nowak
Katedra Taksonomii Roślin
i Ochrony Przyrody
Wydział Biologii, Uniwersytet Gdański
ul. Wita Stwosza 59, 80-308 Gdańsk

Gdańsk, 11.09.2026 r.

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obejmował:

- współudział w opracowaniu koncepcji pracy,
- udział w interpretacji uzyskanych danych,
- udział w przygotowaniu manuskryptu,
- udział w redakcji i korekcie kolejnych wersji manuskryptu.

Sławom Nowak

Podpis współautora

prof. dr hab. Dariusz L. Szlachetko
Katedra Taksonomii Roślin
i Ochrony Przyrody
Wydział Biologii, Uniwersytet Gdański
ul. Wita Stwosza 59, 80-308 Gdańsk

Gdańsk, 22.09.2026 r.

Oświadczam, że mój indywidualny wkład autorski w powstanie artykułu naukowego

„Limited congruence between leaf micromorphology and molecular differentiation in selected Alchemilla L. species"

obejmował:

- nadzór merytoryczny nad realizacją badań,
- konsultacje merytoryczne w trakcie przygotowania pracy,
- udział w przeglądzie, redakcji i korekcie kolejnych wersji manuskryptu.

.....

Podpis współautora

dr Sławomir Nowak
Katedra Taksonomii Roślin
i Ochrony Przyrody
Wydział Biologii, Uniwersytet Gdański
ul. Wita Stwosza 59, 80-308 Gdańsk

Gdańsk, 11.09.2026 r.

Oświadczam, że mój indywidualny wkład autorski w powstanie artykułu naukowego

„Leaf morphometry of selected species of the genus Alchemilla L. (Rosaceae) from Europe"

obejmował:

- udział w przygotowaniu manuskryptu,
- udział w przeglądzie, redakcji i korekcie kolejnych wersji manuskryptu.

Podpis współautora

Gdańsk, 11.09.2026r.

mgr Julia Jaskólska
Pracownia Lichenologii i Mykologii Eksperymentalnej,
Katedra Taksonomii Roślin i Ochrony Przyrody,
Uniwersytet Gdański, ul. Wita Stwosza 59, 80-308 Gdańsk

Oświadczenie o wkładzie w publikację

Oświadczam, że mój indywidualny wkład autorski w powstanie artykułu naukowego: „*Leaf morphometry of selected species of the genus Alchemilla L. (Rosaceae) from Europe*"

obejmował:

- udział w pozyskiwaniu danych,
- udział w opracowaniu koncepcji pracy,
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- udział w przygotowaniu manuskryptu,
- udział w przeglądzie, redakcji i korekcie kolejnych wersji manuskryptu.

Julia Jaskólska

.....
Podpis współautorki

prof. dr hab. Dariusz L. Szlachetko
Katedra Taksonomii Roślin
i Ochrony Przyrody
Wydział Biologii, Uniwersytet Gdański
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.....

Podpis współautora