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Agrostis capillaris L. - A REVIEW OF THE DISTRIBUTION, CHARACTERISTICS, ECOLOGICAL AND AGRONOMIC ASPECTS, AND USAGE

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Abstract

Agrostis capillaris L. (syn. A. tenuis Sibth.) is a perennial herbaceous, hemicryptophyte, native to Romania, distributed frequently from oak to subalpine levels. The circumpolar world distribution shows that the native range is quite extensive and can become adapted to a wide range of other habitats. Still, the literature review showed that in many countries, this species is introduced in grasslands as fodder for animals, as a sports turf and lawn species, and might be invasive in other countries replacing the native species from pastures and other grassland types. A. capillaris might be used as a hyper-accumulator, improving grassland quality; it provides economic value, social benefit, and environmental services.

***Key words**: Agrostis capillaris, A. tenuis, distribution, characteristics, ecological and agronomic aspects, usage.*

INTRODUCTION

Agrostis capillaris L., first published in Sp. Pl.: 62 (1753) is accepted as a species with 165 synonyms, the most used synonym in the literature is *A. tenuis* Sibth. It belongs to Poaceae Family which comprises over 12,000 accepted species (The Plant List, 2013). This perennial and rhizomatous geophyte grows primarily in the temperate biome and according to R.B.G.K. (2022) has a native range in Europe to N. China and Afghanistan, doubtfully present in Morocco and Tunisia and introduced in the Americas, Greenland, Australasia (Batson, 1998), East Asia and the Indian state of Arunachal Pradesh. It has environmental uses, as fodder for animals, sports turf, and as a lawn species. Vasey (1883) published *A. tenuis* as a new species of grass to the San Bernardino Mountains (California), Rapson & Wilson studied the floral phenology (1992a) and responses to light, soil fertility, and water availability (1992b) of *A. capillaris* as an invader in New Zealand (Rumball & Robinson, 1982; Edgar & Forde, 1991). As *A. capillaris* was introduced in New Zealand from Great Britain and comparing the genetic variation of *A. capillaris* within and between populations grown in comparable conditions in New Zealand and Great Britain over a very wide environmental range, Wilson & Rapson (1995) concluded that some of the evidence for non-adaptation in *A. capillaris* in New Zealand is caused by a small gene pool, and insufficient time for sorting of genotypes into habitats. Cho et al. (2016) documented the introduction of *A. capillaris* in Korea in disturbed areas, cemeteries, roadsides, and rough grassland. According to European databases, *A. capillaris* is shown as being a clonal species (Klimešová & Klimeš, 2019), indigenous, hemicryptophyte, with vegetative propagation by runners, storage organs and shoot metamorphoses, reproducing by seeds and vegetatively, its ecological strategy being “csr” (competitors/stress-tolerators/ruderals) (Grime et al., 1988), moderately to well tolerant of mowing, moderately tolerant of grazing and trampling, and with intermediate to high forage value. The studied species is found in many plant associations/habitats (Klotz et al., 2002): Class *Violetea calaminariae* (04.4: Communities of heavy metal soils), Class *Koelerio-Corynephoretea* (05.2: Pioneer communities of hair-grasses), Class *Festuco-Brometea* (05.3: Fescue-brome communities of dry and semi-dry grasslands), Class *Molinio-Arrhenatheretea*

(05.4: Commercially used grasslands), Class *Nardetea strictae* (05.6: Acidic mat-grass communities), Class *Melampyro-Holcetea mollis* (07.3: Acidophilous forest grassland ecotones), Class *Epilobietea angustifolii* (07.4: Communities of clear-felled areas), Class *Calluno-Ulicetea* (08.4: Heather and gorse heathlands), Class *Franguletea* (09.2: Acidic deciduous bush communities), Class *Carpino-Fagetea* (10.2: Mesophilous, summer-green deciduous forests), Class *Quercetea robori-petraeae* (10.3: Birch-oak forests).

According to Mucina et al. (2016) who proposed a vegetation classification widely used in Europe (for applied vegetation science, conservation planning and land management), plant associations comprising *A. capillaris* as diagnostic species are distributed as follow:

a. Order *Agrostio capillaris-Jasionetalia montanae* Foucault 1999 and Foucault 2001 in pioneer herb-rich vegetation on shallow soils on rocky outcrops in the nemoral and boreal zones of Europe (Order SED-02 *Sedo-Scleranthetalia* Br.-Bl. 1955)

b. Alliance *Agrostio capillaris-Peucedanion oreoselini* Reichhoff et Warthemann 2003 (syntax.syn.) Meso-xerophytic forest-edge communities on acidic soils in semi-shady to sunny habitats of temperate and (sub)boreal Europe (Alliance GER-05A *Melampyrion pratensis* Passarge 1979)

c. Alliance *Festuco-Agrostion capillaris* Redžić 1990 (1) in oligotrophic pastures in the lowland to submontane belts of the Western Balkans (Alliance NAR-01H *Achilleo-Arnicion* Horvat et Pawłowski in Horvat 1960)

d. Alliance *Nardo-Agrostion capillaris* Nordhagen 1936 and Nordhagen 1937 and Nordhagen 1943 in moderately chionophilous siliceous mat-grass swards of Scandinavia and as relicts in the Hercynian mountains (Alliance TRI-01B *Nardo-Caricion rigidae* Nordhagen 1943)

Maczey (2016) made a comprehensive and very interesting datasheet on *A. capillaris* covering identification, distribution, dispersal, hosts/ species affected, diagnosis, biology & ecology, environmental requirements, natural enemies, impacts, uses and prevention/control.

MATERIALS AND METHODS

We performed an internet search on plant lists presented online, using *Agrostis capillaris* as the main searchable word, followed by *A. tenuis*.

On Web of Science and Google Academic we used primarily *A. capillaris* and *A. tenuis* together with the words: distribution, characteristics, ecological and agronomic aspects, and usage. Secondarily we used a combination of these words. For access to so-called “grey literature” from the national level, we performed searches on Research Gate and Google Academic using the same method as before.

For distribution of the species at the national level, we used Romanian published books, especially Identification Manuals (Field Guides) for floras (Ciocârlan, 2009; Sârbu et al., 2013), habitats (Doniță et al., 2005; Gafta & Mountford, 2008) and plant associations (Sanda et al., 2008).

RESULTS AND DISCUSSIONS

Characteristics

Agrostis capillaris L. is a perennial tufted species, hemicryptophyte (geophyte) (Figure 1), oligotrophic - mesotrophic species with a circumpolar distribution.

Figure 1: *Agrostis capillaris* habit (left) (original) and clonality (right) (after Klimešová & Klimeš, 2019)

In Romania it is frequent from the oak forest to subalpine levels, in grasslands, shrublands or cleared forests (Ciocârlan, 2000). Ecological preferences of the species are: increased light, growing with difficulty in shade (L_7), with no particular preferences for temperature (euritherm)(T_x) and soil humidity (eurihydric) (U_x), soils of moderate to low acidity (R_5), soils poor in mineral nitrogen (N_3) (Sârbu et al., 2013). *A. capillaris* competes with other species for nitrogen (N) or phosphorus (P). Venterink & Güsewell (2010) conducted experiments showing competition with *Alopecurus pratensis* highlighting that *A. capillaris* is an equal or stronger competitor under P limitation and *A. pratensis* is a stronger competitor under N limitation. The competitive response of *A. capillaris* at the high N: P supply ratio was associated with low root mortality and high root phosphatase activity, but other factors might also be important in competition for P (root longevity, mycorrhizal hyphal length) (Miranda-Apodaca et al., 2020).

Soil microbial diversity (saprophytic, mutualistic, parasitic) has a very important role in ecosystem functioning and interactions with plant roots (Borozan et al., 2015). The seeds of *A. capillaris* can present cultivable endophytic bacteria and, on individuals growing on a long-term Cd/Ni-contaminated plot (Cd/Ni seeds), there are plant- and contaminant-dependent effects on the population composition, significantly improving plant growth. This indicates that inoculation of *Agrostis* with its seed endophytes might be beneficial for its establishment during phytoextraction and phyto-stabilisation of Cd-contaminated soils. (Truyens et al., 2014)

Distribution

The distribution of *A. capillaris*, is highly influenced by altitude and, due to its large ecological variability, it is distributed in the Banat Mountains in grasslands from low hills (237-340 m altitude), to high hills (468-545m altitude), submontane (709-722 m) and mountain levels (sub-level of beech forests and mixed beech and softwood forests), up to 1200 m average altitude, and even to 1446 m (Semenic Mountains, Mount Piatra Goznei) (Săndoiu et al., 2014). In well-lit places, *A. capillaris* is part of the dominant herbaceous species in grasslands: from the Transylvanian Plateau in Brașov County in Mercheașa - Homorod, at 530 m altitude, in Oak (*Quercus robur*) forest area and Jimbor - Homorod at 615 m altitude, in European wild pear (*Pyrus pyraster*) forest areas and from Gurghiului Mountains (Ibănești, Mureș County) at 1150 m altitude in Common beech (*Fagus sylvatica*) forest (Marușca et al., 2020). *A. capillaris* is typical of grassland where it is co-dominant with *Festuca rupicola* (Țucra et al., 1987) which is meso-xerophilic, moderately acidophilic, oligo-mesotrophic, medium tolerant to grazing, trampling, and mowing. The semi-natural grasslands forming the phytocoenosis of the woodland floor has mediocre agronomical value that supports a grazers density of 0.41-0.60 LU/ha, but it has considerable biodiversity importance because it includes many species with indicator values for High Nature Value grassland (Păcurar et al., 2020).

Grasslands with *Nardus stricta* typified by Plant Association *Violo declinatae-Nardetum* Simon 1966 have the widest distribution in higher mountainous regions of Romania (1700-2100 m). They comprise *A. capillaris* in their floristic composition because this species is a remnant from the *Festuco rubrae-Agrostetum capillaris* association that was replaced by *Violo declinatae-Nardetum* due to compaction and acidification of the soil. Following application of lime to increase soil reaction and overgrazing, plant associations with *A. capillaris* as a dominant, characteristic or diagnostic species (i.e. *Hypochoeri radicatae - Agrostetum tenuis* and *Festuco rubrae-Agrostetum capillaris*) are transformed into the Association *Hieracio pilosellae-Nardetum strictae* Pop et al. 1988, which is quite species-poor with soil rich in acidic humus and located in the Vlădeasa Mountains and Măgoaja Hills (Cluj County) at 700-1300 m altitude (Sanda et al., 2008).

In the Maramureș County, Associations *Hypochoeri radicatae-Agrostietum capillaris* Pop et al., 1988 and *Festuco rubrae-Agrostietum capillaris* Horv. (1951) 1952 are located on plateaux or slopes varying between 5 and 50°, showing various exposures, soils rich in organic matter and high variation in altitudes and soil pH, 620-1225 m and pH =

4.37-5.31, and 580-1268 m and pH 4.09-7.29 (Bărbos, 2006).

In areas of clearcut forests, very productive (about 4 t/year/ha) secondary meadows are formed with *Festuca rubra* and numerous other species in the upper levels of the sward and with *A. capillaris* in the ground cover (Doniță et al., 2005). In the *Festuco rubrae-Agrostetum capillaris* Association, *A. capillaris* dominates pioneer and fertilized areas; in *Hypochoeri radicata-Agrostetum tenuis* dominates on soils rich in organic materials. Once the input of nutrients in the soil increases, the *Festuco rubrae-Agrostetum capillaris* with *A. capillaris* as a dominant and characteristic develops into the Association *Lolio-Cynosuretum* Br.-Bl. et de Leeuw 1936 em. R. Tüxen 1937 where *A. capillaris* is a companion species (Sanda el al., 2008; Iliev & Bozhanska, 2023).

Some Romanian habitats (Doniță et al., 2005; Gafta & Mountford, 2008) have *A. capillaris* as a companion species, whilst in other habitats it is dominant or even characteristic (generally dominant or co-dominant species, which provide the largest volume of biomass and define the phytocoenosis) and diagnostic species (characteristics for the plant association from habitat) (Table 1).

Table 1. Romanian habitats, plant association, distribution, and characteristics of areal in which *A. capillaris* vegetate and its status (after Doniță et al., 2005; Gafta & Mountford, 2008)

Natura 2000 habitat	Romanian Habitat	Plant association	Distribution	Areas (ha)	Altitude (m)	Relief	Status of *A. capillaris*
4030 European dry heaths							
	R3112 South-eastern Carpathian heath of bilberry (Vaccinium myrtillus) and heather (Calluna vulgaris)						
		Vaccinio – Callunetum vulgaris Bük. 1942. (Syn.: Nardo – Callunetum Csürös 1964, Agrosteto – Callunetum Resmeriță et Csürös 1966, Arnica montana – Calluna vulgaris ass. Ghișa et al. 1970).					
			Western Carpathians, rare in the eastern Carpathians, at the altitude of beech and spruce forests				
				< 10	600–1750	moderately inclined slopes, manes.	companion species
40A0* Subcontinental peri-Pannonic scrub							
	R3121 Ponto-Pannonic scrub of blackthorn (Prunus spinosa) and spindle (Euonymus europaeus)						
		Euonymo – Prunetum spinosae (Hueck 1931) Tx. 1952 em. Pass. et Hoffim. 1968 (Syn.: Pteridio – Crataegetum monogynae Raâiu et Gergely 1979)					
			In Subcarpathian and Moldova, Muntenia, Transylvanian plateaux, sometimes along rivers in hilly areas, secondary in the place of clearcut sessile oak or mixed hornbeam and sessile oak forests				
				< 100	300–800	moderately inclined slopes	companion species
6240 *Sub-Pannonic steppic grasslands							
	R3413 Pannonic-Balkan meadows of Festuca rupicola and Cleistogenes serotina						
		Cleistogeno – Festucetum rupicolae (Soó 1930) Zólyomi 1958 corr. Soó 1964					
			Banat, Danube Clisura, Ardeal plaine				
				About 40.000	100–350	very slightly inclined slopes, flat ground.	companion species
	R3711 Dacian meadows of Nardus stricta and Molinia caerulea						
		Nardo-Molinietum Gergely 1958					
			Maramureș, Transylvania				
				20–25	350–400	Depressions with slightly inclined slopes	Among dominant species
6410 Molinia meadows on calcareous, peaty or clayey silt-laden soils (Molinion caeruleae)							
	R3713 Anthropogenic meadows of Juncus tenuis and Trifolium repens						
		Juncetum tenuis (Diemont, Siss. et Westhoff 1940) Schwik. 1944					
			River terraces and floodplains in Transylvania, Muntenia, Moldova				
				25–30	100–500	Plane or slightly inclined areas	companion species
6510 Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis)							
	R3716 Danubian-Pontic meadows of Poa pratensis, Festuca pratensis and Alopecurus pratensis						
		Poetum pratensis Răv., Căzac. et Turenschi 1956, Ranunculo repentis – Alopecuretum pratensis Ellmauer 1933, Agrostideto-Festucetum pratensis Soó 1949					
			Rivers' floodplains from Transylvania, Banat, Oltenia, Muntenia, Dobrogea, Moldova.				
				1–2 (300–400)	100–350 (400)	River-terraces in the plain, flat areas or with very slightly inclined slopes	companion species
6520 Mountain hay meadows							
	R3803 South-eastern Carpathian meadows of Agrostis capillaris and Festuca rubra						
		Festuco rubrae – Agrostetum capillaris Horvat 1951.					
			Subcarpathian hills, Mehedinți and Transylvanian plateaux, Dorna Depression, Obcinele Moldovei.				
				400–500	350–700	low inclined slopes, southern and eastern expositions	Characteristic and diagnostic species

No Natura 2000 habitats							
	R3114 Cut forest with raspberry (Rubus idaeus)						
		Fragario – Rubetum (Pfeiffer 1936) Siss. 1946 (Syn.: fit. Impatiens noli-tangere Dihoru 1975)					
			All Romanian Carpathians, at the altitude of beech forests				
				> 100	700–1400	moderately inclined slopes	companion species
	R3801 South-eastern Carpathian meadows of Trisetum flavescens and Alchemilla vulgaris						
		Cerastio holosteoidis – Trisetum flavescenti Sanda et Popescu 2001 (Poo – Trisetum flavescetis auct. rom. non Knapp 1951), Trisetetum flavescentis (Schröter) Brockmann 1907					
			Lower and middle hilly levels of South-East Carpathians				
				10.000–12.000	650–800	Very low inclined slopes, northern or north-eastern exposition	companion species
	R3804 Dacio-Getic meadows of Agrostis capillaris and Anthoxanthum odoratum						
		Anthoxantho – Agrostetum capillare Silinger 1933.					
			Getic and Moldavian Subcarpathians, Transylvanian Plateau				
				500–600	300–700	Moderate inclined slopes	Characteristic and diagnostic species
	R4165 Forest glades with Betula pendula						
		Agrostis tenuis-Betuletum verrucosae Resmeriță 1970					
			Southern Carpathians: depressions within the mountains (Mestecănișul de la Reci in Covasna County).				
				< 100	490–530	sand dunes alternating with flat ground	Characteristic and diagnostic species

Ecological and agronomic aspects

Permanent grasslands in Romania are sometimes subject to bad management and unfavourable climatic conditions leading to an important decrease in productivity. Grassland degradation consists of changes in plant environment and vegetation structure. The current strategy at national level is primarily to save resources and protect the environment, and secondarily to increase yields (Samuil et al, 2011). External factors affect plant species that respond to them in different ways depending on their biotic (other species coexisting in the same ecosystem) and abiotic interactions (Hart et al., 2009; Miranda-Apodaca et al., 2020).

When applying different types and levels of organic fertilisation and depending on climatic conditions, there is a positive effect of organic fertilisers on sward structure, biodiversity and productivity in permanent grasslands dominated by *A. capillaris*. Thus, the management of organic fertilisers did not affect the biodiversity of these grassland types (Samuil et al., 2008; Razec et al., 2009; Damgaard et al., 2011). The application of nitrogenous fertilisers stimulates growth and depresses P concentration in *A. capillaris* (Minson, 2012). At lower altitudes, mineral N accumulated in the soil almost entirely as nitrate and at highest altitude as ammonium (Harrison et al., 1994).

For semi-natural grassland vegetation characterised by *A. capillaris* and *Festuca rubra*, another category of management might be mowing at least once in every 4-5 years to preserve their floristic structure and avoid the agronomic and ecological degradation of their vegetation caused by abandonment (Păcurar et al., 2015). Grazing and mowing, as a mixed management practice, might still degrade the pasture because these grasslands are dominated by species sensitive to grazing and medium resistance to trampling (Voşgan et al, 2015).

Individuals of *A. capillaris* exposed to previous root herbivory had significantly more infection by arbuscular mycorrhizae than individuals with no exposure (Johnson et al., 2013, Borozan et al., 2015).

In Călimani National Park, on waste dump deposits resulting from mining activities, the natural reconstruction (without human intervention) of the plant communities started (primary vegetation type) with *A. capillaris* (among other species) as the dominant species with a clumped distribution (Oprea et al., 2008).

Plants from sites with a high heavy metal concentration adapt more easily to new contaminants. *A. capillaris* shows two types of tolerance: induced or constitutional. Genetically based induced tolerance occurs in individuals after long-term contact with high concentrations of metals in the soil, resulting in contamination-resistant populations due to selection pressure (Budak et al, 2006). Constitutional tolerance occurs in individuals not stressed by selection, and when in contact with high concentrations of heavy metals in the soil develop tolerances depending on species, variety, and developmental phase. Individuals living on soils rich in heavy metals have developed two methods of dealing with contamination (Fitter & Hay, 2012; Kraj et al., 2021):

1. avoidance of the stress factor throughout reducing the quantity of metal uptake from the soil by changing the pH in the rhizosphere, secreting organic acids that limit the availability of metals, mycorrhizae, etc.
2. accumulation throughout uptake of the contaminants and storing them in the roots and maintaining low content in the shoots.

Testing for copper tolerance on populations of *A. capillaris* collected from copper mines grasslands (Cu.Gr.) and uncontaminated nearby ordinary pasture (NonCu.Gr.) showed that: a) growing on Cu.Gr., individuals are copper tolerant; b) individuals from NonCu.Gr. growing very close to Cu.Gr. show absence of copper tolerance; c) the character of copper tolerance has high heritability (McNeilly & Bradshaw, 1968; Whiteley & Williams,1993; Bes et al., 2013).

Usage

Grasslands are important as global sinks and sources of atmospheric carbon (Murray et al., 2004). Grasslands comprising *A. capillaris* are exploited for mowing and grazing in a semi-extensive mode, their areas being under-exploited (Cirebea et al., 2016) or in an intensive mode, their areas being over-exploited (Nicoară et al., 2020; Onete et al., 2020; 2021).

These types of grasslands, traditionally managed, keep their high species diversity thus have high nature conservation value. Their conservation depends on many factors, including the response of the plant species composition to changes in climate variables. In these grasslands, *A. capillaris* and *F. rubra* exchange co-dominance in response to changes in temperature and humidity as the major factors in climatic fluctuations (Păcurar et al., 2014).

For usage of grasslands containing *A. capillaris* as pasture and haymaking, we must consider the method and period of harvest because these factors might affect the increase in yield and crude protein content (Iliev et al., 2022)

Heavy-metal mine areas are naturally colonised by metal-tolerant (Kiss et al., 1998), pseudo-metallophyte (Pandey et al., 2023), or facultative metallophyte (Minson, 2012) ecotypes of *A. capillaris* which can be used for phyto-extraction and phyto-stabilisation of polluted sites with the addition of bark compost as well as mycorrhizae (Truyens et al., 2014).

The best result was found for the combination of water works granules and mycorrhiza. At the end of the vegetative growth season, the solution concentration of most environmentally critical elements was below those of untreated systems (Ietswaart et al., 1992; Macklon et al., 1994; Malcová et al., 2003; Karlsson et al., 2012; Williams et al., 2013; Nicoară et al, 2014).

The efficiency of phytoremediation is achieved by altering some soil characteristics (pH, precipitation, binding compounds or stimulating redox levels). These soil characteristics can act both synchronously or independently. For instance, Pb is precipitated as phosphate in the roots of *A. capillaris* (Emam et al., 2021).

CONCLUSIONS

Agrostis capillaris L. (syn. *A. tenuis* Sibth.) is a perennial herbaceous, hemicryptophyte, clonal plant species. The circumpolar distribution shows that the native range is quite extensive and can become adapted to a wide variety of other habitats. *A. capillaris* is a native species in Europe (except the Balearic Islands, Corsica, Sardinia, Sicily and including European Russia west of the Urals) and Asia, has status doubtful in Morocco and Tunisia (Africa), is not native in most of Asia, Australasia, North and South America. The literature review showed that in many countries, this species is introduced in grasslands as fodder for animals, as sports turf and a lawn species, and might be invasive in other countries replacing the native species of pastures and other grassland types. The studied species is met in many plant associations and habitats according to both foreign and Romanian literature. In Romania, *A. capillaris* is native and forms semi-natural permanent grasslands or pioneer vegetation types on waste dumps and is naturally distributed from hill to mountainous and subalpine regions, in many plant associations as a companion species and in others as a characteristic and diagnostic species.

Grasslands comprising *A. capillaris* are used for grazing or mowing, and their maintenance in space and time is strongly correlated with impact intensity.

A. capillaris might be used as a hyper-accumulator, improving grassland quality, as well as providing economic value, social benefit, and environmental services.

The management of permanent grasslands, via usage, type of control and period and intensity of fertilisation, has a great influence on productivity, species composition and structure of vegetation, species dominance and biodiversity (species of plants, underground and above-ground invertebrates, and vertebrates). Natura 2000 habitats identified by plant associations comprising *A. capillaris* are multiple at national and international levels, showing the necessity of habitats conservation.

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