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BOTANICAL CHARACTERISTICS, TOXICITY AND CONTROL OF BRACKEN FERN (*PTERIDIUM AQUILINUM* (L.) KUHN)

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ABSTRACT

*Bracken (*Pteridium aquilinum *(L.) Kuhn) is cosmopolitan fern, found at varying altitudes on all continents except Antarctica. It is an aggressive colonizer and can appear in various plant communities, but an important characteristic is its ability to dominate in dense patches. Once establish, the deep-set rhizomes are nearly impossible to eradicate. In Croatia, bracken dominate on specific habitat type called "bujadnice" in Lika region, but can also be found in herbaceous layers in following forest communities: As. Betulo-Quercetum; As. Pteridio-Betuletum; As. Potentillo albae-Quercetum pubescentis; As. Castaneo sativae-Fagetum; As. Helleboro nigri-Piceetum. Bracken fern is significant problem for livestock-based extensive agriculture, because it causes a range of syndromes in farm animals including thiamine deficiency, acute hemorrhagic syndrome, bright blindness, enzootic hematuria and upper alimentary carcinoma. Man may consume the toxins of bracken either directly or indirectly. In terms of the economic loss and suffering caused by bracken, it is clearly that some steps must be taken to control distribution of this fern. Timing is important in any management treatment*

of bracken fern. The most effective time for bracken control is summer just after the new fronds have fully expanded and starch reserves in the rhizome are at their lowest level. Two or more annual treatments and combinations of cutting and herbicide are more effective than single treatments or even single annual treatments.

Key words: *bracken, biology, ecology, toxicity, control*

1. BOTANICAL CHARACTERISTICS

Bracken (*Pteridium*) is an important genus of family *Dennstaedtiaceae*. However, genus *Pteridium* is a complex one and nomenclature within the genus is still uncertain and contentious (Bridges et al., 1998, Page, 1976). In global revision of *Pteridium* Tryon (1941) rationalized 135 names that applied to bracken ferns up to that time into a single species *Pteridium aquilinum* with two subspecies: ssp. *aquilinum* and ssp. *caudatum* containing between them 12 varieties, while over 100 other names were discarded trivial or not applying to plants referable to this genus. However, after the morphometric and DNA fingerprinting studies,Thompson (1999) proposed that Tryon's varieties *africanum*, *aquilinum*, *arachnoideum*, *decompositum*, *esculentum*, *latiusculum* and *revolutum* may best be treated as species, while *pseudocaudatum* and *pubescens* as varieties within *latiusculum* and *yarrabense* and *caudatum* as hybrids. DNA fingerprinting further distinguishes an additional grouping of Atlantic Island (Azores, Madiera) and European "aquilinum complex" including var. *aquilinum* and a number of morphotypes at various taxonomic levels (Page, 1989).

Pteridium aquilinum (L.) Kuhn is a polycarpic geophyte that reproduces by spores and widely creeping, branching underground stems. The young leaves of fern (fiddleheads) are curled, covered with silver gray hair, and emerge from the rhizomes early in spring. The large compound mature leaves or fronds are 0.3 to 1.3 m high and 15-45 cm long with blades divided into pinnae (leaflets), and each pinna is divided into oblong pinnules with smooth edges (Figure 1 A&B). Sometimes the bottom pair of them are large enough and give impression of a three-part leaf. Fronds begin to change color in the late summer and die after the first autumn frosts in temperate climate.

The fronds bearing spore are similar in size and shape to the sterile ones. Sori (reproductive organs) are located beneath the outer margins of the leaflets in fertile fronds. The clusters of spore forms nearly unbroken line along the edges of leaflets. The sori are protected by the pinnule margins on one side and a thin membrane (indusium) on other side. Up to 30 million spores may be produced by a single frond. In temperate climate spores ripen in August to September and wind-disperse in August to October. Spore may remain viable for up to 10 years.

Figure 1 A&B. Bracken fern (*Pteridium aquilinum*) in Papuk Nature Park[1]

Photo source: Tomašević M.

When spores germinate, they produce bisexual, gamete-bearing plants about 0.6 cm in diameter and one cell thick. These tiny plants (gametophyte or prothalli) do not have vascular system and require very moist environment to survive. The young spore-bearing fern which develop from the fertilized egg depends on the gametophyte until it develops its first leaf and roots.

The rhizome system consists of two components: the long and the short shoots. The long shoots form the main axis of the fern stem, elongate rapidly, have few lateral buds and do not produce fronds, while the slow growing short shoots arise from the long shoots and produce annual fronds. Roots, which are thin, black and brittle, extend from the rhizome and penetrate deeper in the soil.

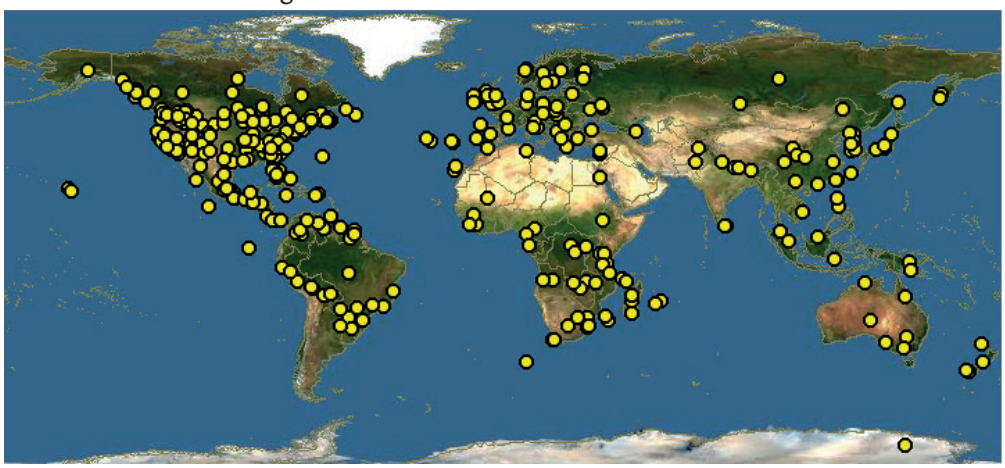
2. ENVIRONMENTAL REQUIRENMENT AND DISTRIBUTION

Bracken is cosmopolitan fern, found at varying altitudes on all continents except Antarctica (Page, 1976; Figure 2). Although bracken could be found at sea level less than 600 m, it is more abundant in the uplands (Grime et al.,1988). This fern can appear in various plant communities, but an important characteristic is its ability to dominate in dense patches (Rodwell, 1992). Bracken fern easily establish itself on areas after fires, so is often referred to as a typical post-fire successional species (Wesche et al. 2000). It also dominated on deforestation areas and land clearance areas due

[1] Autori članka jamče pod punom pravnom i materijalnom odgovornošću da fotografije korištene u radu nisu neovlašteno preuzete te da su korištene u radu bez kršenja autorskih prava.

to agricultural activities, causing severe problems to both farmers and conservationists (Page, 1986; Pakeman et al., 1996).

Figure 2. World distribution of bracken fern



Source: https://www.discoverlife.org/mp/20m?kind=Pteridium+aquilinum&flags=col3:

Bracken fern is an aggressive colonizer of open ground and readily invades pastures and fields. Once establish, the deep-set rhizomes are nearly impossible to eradicate. Because of its tendency to shade out other plant species, and to competes for soil moisture and nutrients, bracken is considered to be among the world's worst weeds (Holm et al., 1979). Moreover, it is listed as an invasive species in some places like Mexico, (Schneider, 2004), Brazil (Portela et al., 2009) Rwanda (Senyanzobe et al., 2020), etc.

Marrs et al., (2000) hypothesize that bracken-dominated communities occupy a mid-successional position between early-successional, semi-natural communities such as grassland, heaths and moors, and late-successional woodlands.

2. 1 Distribution of bracken fern in Croatia

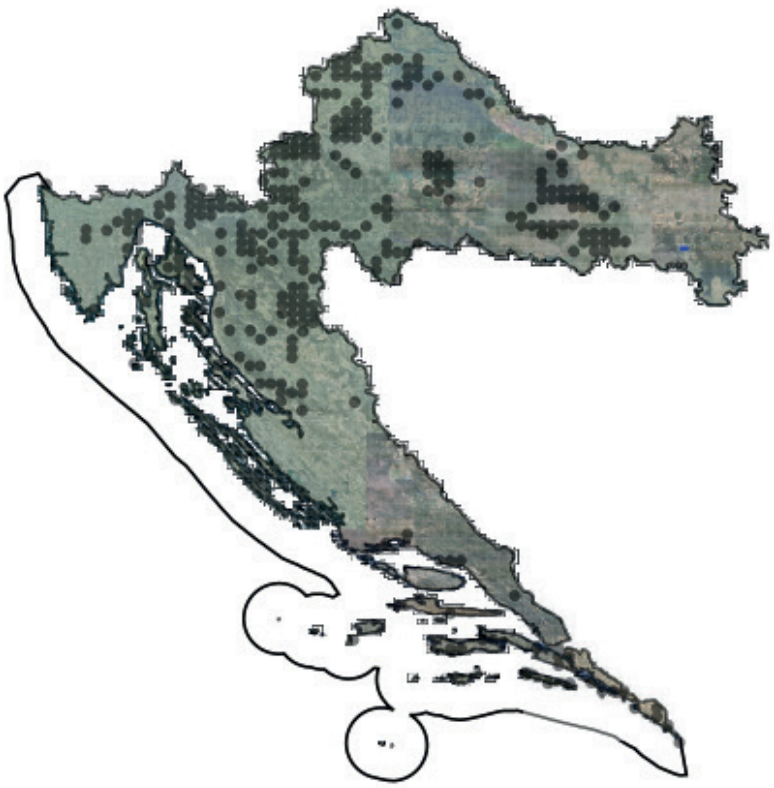
Two subspecies of bracken occur in Croatia; *Pteridium aquilinum* (L.) Kuhn and *P. aquilinum* (L.) Kuhn ssp. aquilinum (Figure 3 https://hirc.botanic.hr/fcd/ShowResults.aspx?hash=1886782308). According to the Croatian National classification of habitats (NKS_2018_opisi_ver5) bracken fern dominate on specific habitat type called "bujadnice" (Pteridium aquilinum; NKS 1-4: C.3.4.1.2.). These habitats were well distributed in Lika region, but nowadays "bujadnice" partially overruns into woods, particularly birch forests, or partly returns into potato or rye fields after the cultivation.

Bracken fern can be also commonly found in herbaceous layer in:

- mixed sessile oak and silver birch wood (As. *Betulo-Quercetum* Tx. 1937) in Gorski Kotar;
- birch and bracken wood (As. *Pteridio-Betuletum* (Rauš et Vukelić 1986) Trinajstić 2004) in Karlovac-Ogulin county, Kordun, Gorski kotar, and in Slavonian mountains Psunj and Papuk

- downy oak wood with white cinquefoil (As. *Potentillo albae-Quercetum pubescentis* A. Horvat 1973) in flysch part of Istria peninsula
- common beech and sweet chestnut wood (As. *Castaneo sativae-Fagetum* Marinček et Zupančić (1979) 1995) in mountain region of northwestern Croatia (Zrinska and Petrova gora)
- spruce wood with black hellebore on dolomite (As. *Helleboro nigri-Piceetum* (Horvat 1958) Trinajstić et Pelcer 2005) in Mala Kapela region and National Park Plitvička jezera.

Figure 3. Bracken fern distribution in Croatia



Source: https://hirc.botanic.hr/fcd/beta/map/search/232-27460?criteria=Rod:Pteridium

3. TOXICITY

All part of the bracken fern, including rootstocks, fresh or dry leaves, fiddleheads, and spores are poisonous to livestock and humans since they contain toxic compounds. Bracken fern causes a range of distinct and well-defined syndromes in livestock. Their occurrence will depend on number of factors and include the quantity of bracken available, its content of toxins, stage of growth, time of year, duration and rate of consumption and the species, sex and age of animals.

Bracken can cause a nervous condition in monogastric animals such as horse and pig. Its earliest signs consist of anorexia and ataxia, but may proceed to convulsion and death. This syndrome is caused by type 1 thiaminase (Evans, 1976) which has highest activity in bracken rhizomes, especially in the summer.

Acute hemorrhagic disease occurs most frequently in weaned calves, but is also recorded in older cattle and sheep occasionally (Sunderman, 1987). The acute disease is the sudden clinical manifestation of degenerative change in the more rapidly growing cells, especially in the bone marrow.

Progressive degeneration of retina which results in blindness can be develop in sheep fed on bracken (Watson et al., 1972). This retinal atrophy leads to an increased reflectance of the tapetum lucidum, seen especially in semi-dark conditions, and which has given the name "bright blindness".

After prolonged ingestion of bracken, cattle and sheep can develop multiple mixed tumorous in the urinary bladder. Carvalho et al., (2006) divided bladder lesions into three main categories: inflammatory lesions, non-neoplastic epithelial abnormalities and tumorous and described in details.

Syndrome of upper alimentary carcinoma like fibrosarcoma of the mandible, maxilla and papillomata of the rumen have been reported for cattle and sheep. Quercetin and immunosuppressive agents that exist in bracken contribute to tumor development (Campo et al., 1992).

Two groups of researchers (Niwa et al., 1983, Van der Hoeven et al., 1983) almost simultaneously published the structure of major bracken carcinogen, now generally known as ptaquiloside (PT). It concentration is highest in the young growing parts of the plant. Epidemiological evidence suggests that some cancers in man might result from direct or indirect consumption of the bracken carcinogens. Ptaquiloside and its carcinogenicity has been shown to pass through the milk of cattle fed on bracken (Alonso-Amelot et al., 1999). Spore of bracken fern may also pose a health risk (Evans, 1984).

Beside toxicity there are other problems associated with this fern. Bracken litter provides an ideal moist and warm habitat for sheep ticks (*Ixodes ricinus*) and spread of tick-borne diseases. Hudson, (1986) explore the association between bracken and ticks and to test the idea that removal of bracken could result in a decrease in tick abundance.

4. CONTROL OPTIONS

Due to bracken rhizomatous rooting system and its ability to produce mass amounts of spores, control and spread of bracken fern can be difficult. Various methods of bracken fern control are grouped under several broad categories: cultural, mechanical, chemical and biological.

4. 1 Cultural control

Different practice to reduce infestation of bracken fern like frequent liming and fertilizer application are useful strategy in upland grassland. Additional planting with preferable forage grasses or herbaceous species such successfully reduced the cover of bracken (Petrov and Marrs, 2000)

4. 2 Mechanical treatment

Mechanical methods like cutting or deep ploughing should be conducted over a number of years for receiving noticeable effect. Also timing of the treatment is also very important, and research indicate that optimal According to Marrs et al. (2000), cutting twice a year, should be done early in the summer allowing rhizome to regenerate a second crop of fronds, and then re-cutting will much faster deplete the resources of the rhizome. By cutting once or twice per year, bracken total dry mass per unit area can be reduced approximately 60% after 5 years (Le Duc et. al., 2000).

4. 3 Chemical control

Using an herbicide to control bracken fern is generally difficult, but herbicide application appears to be used over greater areas than mechanical method of control in many countries (Pakeman et al., 2002). There are many effective chemical options for bracken control with various mode of action Robocker (2017). However, only some of them are allowed for use in Croatia (Štefanić, 2021). Active ingredient, mode of action and time of application herbicides that can be applied in Croatia are listed in Table 1.

Table 1. Herbicide that can be used in Croatia to manage bracken fern

Active ingredient:	Mode of action:	Time of application and growth stage:
Glyphosate	Inhibition EPSP synthase	Apply in autumn at full frond expansion, while plants are actively growing
Dicamba	Synthetic Auxins	Apply in autumn at full frond expansion, while plants are actively growing
Picloram	Synthetic Auxins	Apply in autumn at full frond expansion, while plants are actively growing
Metsulfuron-methyl	Inhibition of Acetolactate Synthase	Apply in autumn at full frond expansion, while plants are actively growing

Source: Authors

The efficiency of glyphosate for initial bracken control has been confirmed by many (Petrov and Marrs, 2000, Robocker, 2017), but this herbicide seek the renewal of the EU authorization (https://www.glyphosate.eu). Effectiveness of all these herbicides listed in Table 1 depends on follow-up control measures, because bracken fern recovers rapidly. Therefore, an integral approach to successful bracken management must be considered (Le Duc et al. 2000), and bracken control has to be seen as part of much larger land use/management strategy (Pakeman et al., 2000).

4. 4 Biological control

There are several biological control agents capable for severely damaging the fronds in spring, but for damaging the rhizome no biocontrol agent capable has yet been identified. Lawton (1988) evaluated potential arthropod species and problems with their use. Two defoliating moths *Panotina angularis* and *Conservula cinisigna* were considered promising, but the research was abandoned because of the costs of field testing and concern of using biological control to manage a native weeds (Cruttwel McFayden, 1998).

The possibility of using pathogenic fungi, either alone or in conjunction with herbicides, to control bracken fern is also being studied. Womack and Burge (1993) considered the imperfect fungus *Ascochtya pteridis,* causal agent of curl-tip disease, as a potential active ingredient of a mycoherbicide for bracken control, while Burge and Irvine (1985) considered *Phoma aquilina* as more pathogenic fungi for bracken control.

5. CONCLUSION

Bracken is aggressive colonizer and can appear in various plant communities. In Croatia, bracken dominate on specific habitat type called "bujadnice" in Lika region, but can also be found in herbaceous layers in some forest communities where it can cause significant problem for livestock-based extensive agriculture. Cultural, mechanical, chemical and biological treatments can be used in bracken management. The most effective time for bracken control is summer just after the new fronds have fully expanded and starch reserves in the rhizome are at their lowest level. However, two or more annual treatments and combinations of cutting and herbicide are more effective than single treatments or even single annual treatments.

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BOTANIČKA OBILJEŽJA, TOKSIČNOST I SUZBIJANJE BUJADI (*PTERIDIUM AQUILINUM* (L.) KUHN)

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SAŽETAK

*Bujad (*Pteridium aquilinum (L.) Kuhn *je kozmopolitska paprat, prisutna na različitim nadmorskim visinama svih kontinenata, izuzev Antartike. Biljka je agresivni kolonizator i prisutna je u različitim zajednicama, ali njena osobita karakteristika jest sposobnost da dominira u gustim nakupinama. Nakon što se pojavi na nekom području, dubok sustav rizoma je gotovo nemoguće iskorijeniti. Bujad u Hrvatskoj dominira na specifičnom stanišnom tipu zvanim „bujadnice "u Lici, ali je također prisutna u prizemnom sloju šumskih zajednica As. Betulo-Quercetum; As. Pteridio-Betuletum; As. Potentillo albae-Quercetum pubescentis; As. Castaneo sativae-Fagetum; As. Helleboro nigri-Piceetum. Bujad predstavlja značajan problem u ekstenzivnoj stočarskoj proizvodnji jer kod životinja uzrokuje niz simptoma kao što su deficijencija tiamina, akutni hemorhagični sindrom, sljepoća, enzotična hematurija i karcinom gornjeg gastrointestinalnog trakta. Čovjek također može na direktan i indirektan način konzumirati toksine bujadi. Usljed ekonomskog gubitka i patnji životinja uzrokovanih konzumacijom bujadi, potrebno je poduzeti odgovarajuće mjere za kontrolu populacije bujadi. Pri tome je vrijeme suzbijanja*

vrlo značajan moment.Najučinkovitije vrijeme suzbijanja bujadi jest u ljeto kada su se nadzemni izdanci potpuno razvili, a rezerve škroba su na najnižoj razini. Dva ili više tretmana suzbijanja bujadi godišnje, po mogućnosti kombinacijom košnje i herbicida su mnogo učinkovitije nego samo jedan pojedinačni ili čak samo jedan puta na godinu.

Ključne riječi: *bujad, biologija, ekologija, toksičnost, suzbijanje*

INTERDISCIPLINARNA PODRUČJA ZNANOSTI