



Geliş(Received) :30/11/2019
Kabul(Accepted) :06/12/2019

Derleme Makale/Review Article
Doi:10.30708.mantar.653329

Single name nomenclature of fungi and its some reflections since 2011 especially in Turkey

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Abstract: Despite some opposing mycologists in the fungal systematics, dual nomenclature (*meaning that a perfect i.e. sexually reproducing fungal species different name, the same species as an imperfect i.e. that fungus has asexual reproduction different name given*) was quitted along with publishing “The Amsterdam Declaration on Fungal Nomenclature”. Developments related to the subject since 2011 and the effects of the single fungal taxonomic system are discussed. Full implementation of the single name nomenclature system may take a long time. It is difficult to abandon the fungal names in the publications before 2013, and these sources are still used in all over the world. Change can take place over time. It is seen that the old name of some species whose name is changed is still used in many publications.

Key words: Fungal taxonomy, single name nomenclature, one fungus one name.

Fungusların tek isimle isimlendirilmesi ve 2011’den bu yana özellikle Türkiye’deki yansımaları

Öz: Mantar sistematisindeki bazı muhalif mikologlara rağmen, çift isimlendirme (yani; eşeyli üreme gösteren fungus türlerinin farklı, eşeysiz üreyen aynı fungusun farklı tür adı alması) uzun zaman önce “Amsterdam Deklarasyonu - Fungal isimlendirme” makalesi ile yayınlanmıştır. 2011’den bu yana konuyla ilgili gelişmeler ve tek fungal taksonomik sistemin etkileri tartışılmaktadır. Tek isim isimlendirme sisteminin tam olarak uygulanması uzun zaman alabilir. 2013’ten önce yayınlardaki mantar isimlerini terk etmek zor olmakla birlikte bu kaynaklar hala tüm dünyada kullanılıyor. Değişim zamanla gerçekleştirilebilecektir. Adı değiştirilmiş bazı türlerin eski isimlerinin hala birçok yayında kullanıldığı görülmektedir.

Anahtar kelimeler: Fungal taksonomi, Tek isimle isimlendirme, bir fungus bir isim

Introduction

Although there have been many researches on fungal classification since the 1600s, all the main fungal classification schemes proposed to date are different from each other. According to Ainsworth's (2009) book on the history of mycology, one of the first classifications, similar to the current fungal classification schemes, was made by Anton de Bary in 1866 (Scheme: Phycomycetes,

Hypodermii, Basidiomycetes, Ascomycetes) (Ainsworth, 2009).

Although fungal classification has been made by considering different characters from the past to the present, it is interesting that the diagrams of how many phyla or how many large groups of fungi do not look exactly like each other, reveal that confusion is a controversial situation. What could be the reason or the reasons? This is difficult question but various comments



can be brought. Bones, lignin or similar hard and durable structures are not found in fungi, so fossil records are not available more because of structures of fungi are not suitable for adequate fossilization. This situation complicates the establishment of phylogenetic relationships between fungal groups. For this reason, the fungal system is based on the phenotypic features (reproductive structures, morphologies, spore types, colonial characteristics, etc.) of fungus that have been living for a long time (even still).

Sexual reproduction structures are important in fungal taxonomy, but all fungi are not reproduces sexually or their sexual stages are not recorded yet. So discussions on fungal taxonomy continue. With the discovery of PCR in 1983 (Wessner et al., 2013), molecular studies of fungi have gained speed and fungal taxonomy has improved. According to Levetin et al. (2016), in the 20 years between the 1995 and 2015, DNA sequencing resulted in a solution for 8 fungal phyla, three of which were Zygomycota, Ascomycota and Basidiomycota which contain important aeroallergens. Although there is currently no fungal classification scheme adopted by all mycologists, there are four fungal groups in almost all schemes: Chytridomycota, Zygomycota, Ascomycota and Basidiomycota. Already, Blackwell and Spatafora (2004) reported that 95 % of fungal species belonged to Ascomycota and Basidiomycota.

Although molecular studies have benefits, they also have several disadvantages. For example, Deanna A. Sutton (2014) wrote on the subject on the website: "http://www.swacm.org/annualmeeting/2014/handouts/20140903/WS5_ChangingTaxonomyNomenclatureinMedicalMycology_Sutton.pdf" (access: 22 October, 2018). 20 % of the information in the bank may not be accurate for species level identifications or may not be up to date, the DNA quality used may not be good, and the sample used may have more than 1 fungus; the DNA of some species is difficult to remove; it may be necessary to know the phenotypic properties to select appropriate targets; molecular methods can be performed by people with little knowledge of the classical fungal identifications, and this may lead to wrong identification. In addition to fungal morphological experience, if a scientist prefer DNA sequencing methods, identification results depend on the DNA sequencing should be performed together with sequence results of type cultures. Prakash et al. (2017) stated that traditional fungal identification methods based on morphological-phenotypic characters have the potential to produce time-consuming and inaccurate results. Therefore, it is more valuable to using combine

current conventional methods with molecular methods. The individual application of both methods alone does not solve the problems. Although fungi were classified on the basis of reproductive structures, then other main characters were also considered; examples: whether or not flagella, formation of mycorrhizal, biochemical structure of cell wall, dicaryotic structure, whether or not parasitic.

In fact, the fungal system is not only discussed in itself, which organisms are fungus, which are not? Even this issue is discussed among mycologists and there may not be full consensus. For example, according to Blackwell (2011), biologists working with fungi discussed the which organisms to be accepted in fungi within the last 200 years (this period is specified in 2011). Logic, functioning, mechanism, fungal terms and it is difficult to grasp the changes over time in fungal systematic and researchers who are starting to work on this issue a difficult environment is waiting. There are also a lot of fungal terms and it is difficult to learn all.

This is one of the main objectives of the study is to contribute to the awareness of single nomenclature for fungal taxonomy, especially in Turkey and surrounding countries and to raise awareness.

Single name nomenclature of fungi

Some fungi show both the sexual and asexual reproduction. Fungal reproductive structures are important in fungal taxonomy. For example, *Aspergillus* genus has both sexual and asexual states. While its asexual stage is named as *Aspergillus*, sexual stages have more than one name. However, according to the decision made at the meeting held in Amsterdam by CBS in 2012, it was decided to use the name *Aspergillus*. Also a similar situation exists for some fungal species names. Asexual and sexual stages of a fungal species are called by separate names. In fact, more than one name is used for the same species. If sexual life cycle of a fungal species is either unknown or absent are collected in Deuteromycetes (= Fungi Imperfecti). However, after the sexual reproduction is found, the fungal species is actually taken into the class it belongs to. The history of this situation dates back about 150 years. In the mid-19th century, the French brothers Charles and Louis René Tulasne observed that the same fungus produced more than one reproductive structure under the microscope (sexual - teleomorphic and asexual - anamorphic stages). The sexual and asexual stages of such fungi were given separate names. Over time, the researchers concentrated on one of these names and different names of the same species increased and became widespread



(Milius, 2014). Likewise, according to Hibbett and Taylor (2013), the dual-classification emerged in the 19th century and increased with the use of sexual morphologies in the Linnaean classification of plants. According to the <http://www.fungaltaxonomy.org/files/6813/9241/1345/Naming_and_Outline_of_Dothi_deomycetes_2014.pdf> website (Wijayawardene et al., 2014), the dual-classification in fungi was proposed by Saccardo in 1904 to solve the chaos caused by sexually and asexually phases and was accepted in the International Botanical Congress (IBC) in 1905 in Vienna (Austria). Although it seems illogical for a species to have more than one name, this situation has continued as it is. Because the morphology of sexual reproduction structures was considered to be superior to that of asexual forms. However, in the late 1980s, when the sexual characteristics began to show DNA variations, they lost their superiority. One of the first official meetings on this issue was organized by CBS-KNAW (new name: Westerdijk Fungal Biodiversity Institute) (<http://www.westerdijkinstitut.nl/>) in April 2011 in Amsterdam under the name "One Fungus One Name = 1F1N". This meeting also was attended by many mycologists from Turkey.

In July 2011, before the International Botanical Congress in Melbourne, Australia, a group of mycologists gathered, and Scott Redhead prepared a text with three options to change the dual-classification rule. His most radical proposal was the removal of the double-nomenclature option from the "Article 59" (Milius, 2014).

"One fungus one name" system is more simple and comprehensible that avoided giving different names to the sexually and asexually reproducing members of the same species. However, this system has some problems and it is doubtless that these problems will take years to resolve. According to Hibbett and Taylor (2013), there are very important and common species belonging to some genera, but according to the single name nomenclature, not all of these species may be within that genus. For example, *Penicillium rubens* is the original source of penicillin, *Penicillium marneffeii* is pathogenic in humans, *Penicillium camemberti* and *Penicillium roqueforti* play an important role in the production of cheese and all of these species were in the genus *Penicillium* (Hibbett and Taylor, 2013). However, the name of *Penicillium marneffeii* has changed [new name: *Talaromyces marneffeii* (Segretain, Capponi & Sureau) Samson, Yilmaz, Frisvad & Seifert] and this species has been transferred to the genus *Talaromyces* (Samson et al., 2011). In this case, *T. marneffeii* should be included with the old name (*P. marneffeii*) in the publications before 2011 and with the

new name in the later publications. Different fungal names can be taken into account in different hospitals in different countries. The fungi concern many researchers working in different scientific disciplines such as medicine, veterinary medicine, phytopathology, food science, biology, environment, engineers, and pharmacology. However, it is difficult to think that all of these researchers have a good knowledge and more information of fungal taxonomy. Known, accepted and widespread of the fungal names that change due to the single name nomenclature system will take time.

The fact that a fungus genus or species has two different names caused various problems in time. For example, when it is desired to identify fungi that cause diseases in humans, animals or plants, it may be difficult to decide which of the pathogenic species is the correct name because of the different names of these fungi in the literature. R.A. Samson pointed out this problem at "6th Trends In Medical Mycology" in Copenhagen in October 2013 and stated that giving different names to different stages of a fungus caused confusion. For the discussion of this issue, CBS-KNAW Fungal Biodiversity Centre (current name: Westerdijk Fungal Biodiversity Institute) started a series of symposiums starting in April 2011 and which will be held in April each year. The first symposium in April 2011 was called "One Fungus One Name", followed by "One Fungus Which Name" (2012), "One Fungus Which Gene(s)" (2013) and "One Genera and Genomes" (2014). The subject of the 5th Symposium held in the Netherlands on 22-24 April 2015 was designated as "Second International Workshop on Ascomycete Systematics". A declaration on the issue signed by the participants of the symposium in 2011 was published in the journals *Ima Fungus* and *Mycotaxon* under the title of "The Amsterdam Declaration on Fungal Nomenclature" (Hawksworth et al., 2011). Single name nomenclature system was mainly explained by this declaration and has been highly cited (280 citations as of June 26, 2019; source: GoogleScholar. Also it takes 197 citations in scientific journals covered by *Web of Science* Database, access: June 26, 2019). Intense citation also shows interest in the subject.

According to the decision taken at the International Botanical Congress in Melbourne in July 2011, the code "International Code of Nomenclature for algae, fungi, and plants" was adapted to the "one fungus-one name" (see Norvell, 2011 for decision taken). According to John McNeill, the code name, formerly the "International Code of Botanical Nomenclature", has been "International Code of Nomenclature for algae, fungi, and plants" [Hawksworth, 2011; Norvell, 2011; <http://mpb.ou.edu/ben>



/441/ibc_nomenclature_2011.pdf) (Access: 23 October 2018)].

Hibbett and Taylor (2013) reported that there are 4 major changes in the single name nomenclature of fungi:

- Elimination of the obligation to description in Latin Language.

- Electronic publications become valid.
- The quitted of the dual-nomenclature.
- Registration of new species in fungal databases such as www.indexfungorum.org, www.mycobank.org and <http://fungalinfo.im.ac.cn/fungalname/fungalname.html>.

The Amsterdam Declaration accepts the transition to the “single-name nomenclatural system” and provides the protection of the names. Between the two names, the previously-given name has the priority to use. For example; Hawksworth (2015) has stated that of the asexual *Penicillium* name in 1809, of the sexual *Eupenicillium* name was given in 1892, so the previously-given *Penicillium* name is valid.

If a fungus has both teleomorphic and anamorphic stages, then the holomorphic name will be the name of one of these stage. Since the January 1, 2013, only one name of a fungus has been beginning to use. In this case, all valid names may be proposed as the name of a species, regardless of which stage it belongs to. Lichens were excluded from the system (Hawksworth, 2011, http://en.wikipedia.org/wiki/Teleomorph,_anamorph_and_holomorph).

Only one valid name will be accepted at the genus and species level for fungal taxa. Starting from 2013, the names given separately for the teleomorph or anamorph of a species have become invalid. The fungal taxa should be either Latin or English diagnostics in a valid publication. The final versions of the electronically published taxonomic changes should be in PDF format and should include ISSN for journals or ISBN numbers for books. In other words, even if a work containing taxonomic information is published electronically in PDF format with no specific number of volume, number, year and page numbers (by giving the DOI Number), no change can be made later. Fungal names should take place in well-known places such as mycobank.org. (Yoshitaka Ono, 2012: Link: http://www.elsevier.com/_data/promis_misc/myc_Fungal_Nomenclature.pdf, access: 23.10.2018).

Some effects of single name nomenclature

There are various publications on the effects of the single name nomenclature system. For example, Wingfield et al. (2012) stated that the single name

nomenclature contributed to plant pathology studies. Historical priority is important when selecting a fungal name. Examples: *Trichoderma* name in 1794 should be used, not *Hypocrea* named in 1825 or *Alternaria* should be used in 1817 not *Lewia* in 1986. But sometimes it can be difficult to follow this rule. Because it may be difficult to disregard common and known fungal names and to choose only slightly known and uncommon names because the name is older. Because after the abandonment of common and known names, it takes time to get used to the lesser known and non-common names. For example, a common species, *Fusarium graminearum*, can be released and use of *Sphaeria zaeae* or *Dothidea zaeae* (www.indexfungorum.org), which is the synonym of this species, can be problem. The names of the fungal genera and species that are widely known and common in the literature should be preserved. For example, Pitt and Taylor (2014) stated that the name *Aspergillus*, which is an ancient and important genus and which contains many economic and socially important species, should be preserved. Geiser et al. (2013) suggested the conservation of *Fusarium* name due to its importance in plant pathology, mycotoxicology, medicine and basic research. Sometimes the number of species in a genus can be very high, and these species can be common species known as medical or economic. For example, the name of such a genus should be used even if it is new to the other genus, using the older synonym name may cause problems because the number of species in this genus may not contain less and more common types.

The use of a single name from a fungus will take some time to settle. Although it is 8 years after the single name nomenclature has been proposed, it is seen that still changing names are used. Example: According to the indexfungorum.org website, *Neosartoria hiratsukae* is the synonym of *Aspergillus hiratsukae* but old name was used in some articles published in 2018 (Toth et al., 2018; Garza et al., 2018). Fungal names in articles or books written after 2011 are more likely to be used than the single name nomenclature. However, it is not possible to correct the old names in the works which were published before 2011 and cannot be updated and these works are in use. Moreover, not all of the people reading this work may have specialist in mycology. As a result, it will take time to link the literature with the old names and the literature on the new names. Moreover, “one name one fungus” declaration is not only interested in mycology scientist, it is also important to have information of editors and reviewers about the current conditions in the relevant science. However, the contribution of databases such as



indexfungorum.org and mycobank.org is important and the control of the names from these places is valuable for the prevention of the complexity. The single name nomenclature has also had an impact on the fungus of medical importance. Because sometimes the names of fungal diseases are derived from the genus name that causes the disease. For example, in a publication (Wang et al., 2018a), the name of *Penicilliosis marneffei* was used for the disease caused by *Talaromyces marneffei*. This shows that the new names of the fungal species that are changing the name and the names of the diseases due to these names will take time and will be used widely.

Another effect of the new rules in the fungal taxonomy has been on some scientific journals. For example, the *Mycoscience* Journal published a text stating that the authors adapted the spelling rules to this single name nomenclature (http://1.elscdn.net/promis_misc/myc_Fungal_Nomenclature.pdf, access: October 26, 2018). Alerts are also available in *Mycologia* Journal, link: http://journals.taylorandfrancis.com/tfo/UMYC/Mycologia_IFA_2018.pdf, access: 26.10.2018>. The single name nomenclature has also begun to influence the content of some MSc or doctorate theses. For example, in the thesis prepared by Aylward (2014), the effect of the single name nomenclature on the genus *Knoxdaviesia* was discussed. Kepler et al. (2013), in relation to the phylogenetic insertion of insect pathogens in the genus *Polycephalomyces*, made an application of the single name nomenclature.

Many scientific groups work on which fungus names to choose. One of them is International Commission of *Penicillium* and *Aspergillus* (ICPA). Kirk et al. (2013), according to the International Code of Nomenclature for algae, fungi, and plants", have published a list of fungal species to be protected after the single name nomenclature. In the list, there are 6995 names among 17072 published genera [But Crous et al. (2014) indicated that the number of fungal genus is more than 18,000]. (In a book published by Clements and Shear in 1973, it was written in 1909 that there were 5,000 fungal species in the 2909 fungal genera; please note how much the number has increased over time). In addition, Rossman et al. (2015) also provided a list of genus names to be protected in *Dothideomycetes*. Also Visagie et al. (2014) indicated that the *Penicillium* species need to be protected.

Hong et al. (2012) stated that over 10,000 fungal species will be renamed together with the single name nomenclature. Considering that there are about 120,000 fungal species, the percentage of fungal names that need to change is approximately 8.5 %. It is obvious that

changing names are quite few. There will be no sudden change that will take time to be proposed, accepted, published and disseminated.

With the change of the International Code of Nomenclature for algae, fungi and plants (ICNAFP), the following question is raised: Should the *Aspergillus* genus be a large genus or be divided into many small genus? The International Commission of *Penicillium* and *Aspergillus* (ICPA) preferred the first option. Kocsube et al. (2016) indicated that the *Aspergillus* genus is a monophyletic, multi-gene phylogeny and extruder profiles with the evidence from. de Hoog et al. (2017) reported that *Trichophyton*, a major genus of dermatophytes, was a polyphyletic, suggesting an increase in the number of dermatophyte genus but a decrease in the number of species and proposed two new types of dermatophytes: *Guarromyces* and *Paraphyton*.

When we look at some of the changing fungal names such as *Penicillium marneffei* after 2011, we see the following. One of the changing names is *Penicillium marneffei* [new name is *Talaromyces marneffei* (Samson et al., 2011)]. After 2011, *Penicillium marneffei* name was used in some publications originated from Turkey (Ergin et al., 2013; Çetinoğlu and Ursavaş, 2014; Çelik, 2013; İnci et al., 2018). There is only one publication in *Web of Science* database that contain *Penicillium marneffei* species name originated from Turkey (Sahin and Gokova, 2006) and it is normal to use the name because of it was published before 2011. There are 842 publications for *Penicillium marneffei* name in the *Web of Science* database. Since the name changes in 2011, it is better to consider the publications between 2012-2019 (June 27, 2019). In this case, "*Penicillium marneffe*" name is take place in the 312 publications in mentioned database. The name is still widely used. For example: 2012: 46 publications, 2013: 41, 2014: 39, 2015: 49, 2016: 39, 2017: 37, 2018: 46, June 27, 2019: 15. When we write "*Talaromyces marneffei*" for search the same period, there are 133 publications (using this name is increasing after 2014. 2015: 14 publications, 2016: 23, 2017: 28, 2018: 39; June 27, 2019: 15). According to this data, the old name is used more and using old name more than new name in *Web of Science*. Not only in Turkey, as in other countries continue to use the old names, examples: Yu et al., 2018; Zainudin et al., 2018; El Shehry et al., 2018; Wang et al., 2018; Al-Oebady, 2018; Wang et al., 2018 (a). But there are also those who use the new name, for example: Vanitha et al. (2018). Both are used in some publications such as Xu et al. (2019).

We can not observe to important possible effects of new fungal system in Turkey. But, Turkish researchers



takes Mycobank numbers when published new fungal species, for example Sesli and Vizzini (2017). Also Turkish researchers descriptions new fungal species in their papers in English and journals are only electronics.

There are very different and interesting point including some fungal species on some fungal resistance test standards. For example; MIL-STD-810G Method 508.7 is a current version of military standard test method providing stringent anti-fungal performance testing of materials and products (MIL-STD-810G, 2014). The last version is published at 2014 that is after one fungus one name date. This standard method includes some test microfungi and names of these fungus used in text as “*Aspergillus flavus* (ATCC 9643), *Aspergillus versicolor* (11730), *Penicillium funiculosum* (ATCC 11797), *Chaetomium globosum* (ATCC 6205) and *Aspergillus brasiliensis* (formerly known *A. niger*)”. When we check these fungus names from index fungorum; i) *P. funiculosum* has been *Talaromyces funiculosus* since 2011, ii) *A. brasiliensis* has been *A. brasiliensis* since 2007 not *A. niger*. It is clear that there are very huge confusion. Unlike the taxonomic dimension of this issue, if the subject we talked about is standard methods, the main question here what is the main fungus of this standard method. There are a lot of laboratory that accredited about this standard method and there are a lot of tested materials and results unpublished! Moreover, there are a lot of similar standards in cosmetic (challenge test; EN ISO 11930), material science (JIS L 1921:2015 Textiles, ISO 846:1997(E): Plastics, ISO 13125:2013(E): Fine ceramics, JIS A 5756:2006 Building gaskets and Building structural gaskets) and e.t.c.

Other possible effects in future

The new fungal taxonomic system contains significant changes. There have been many changes and will be in the future. Various mycology books are published in different languages. For example, Hoog (2013) stated that program rewriting of standard books on fungal taxonomy and revising the course programs. Before 2011, there is nothing to do for those that are physically printed, but new editions and new editions of previous editions will have to change quite a bit. It will take time for the new system to be understood, digested and included in its works by the authors. In addition, there are mycology courses in various undergraduate, graduate and doctorate programs (Biology, medicine, agriculture, veterinary medicine, environmental sciences, food, engineer, pharmacy, test laboratories etc) in universities around the world. Course notes, books, lectures used in these courses etc, all educational materials will need to

be updated as well. In addition, in various countries of the world, it is expected to update the course documents for specific areas of mycology. When further details are found, there will be other changes; For example, there may be a need to update the new names of fungal pathogens that are included in the drug prospectuses and in the single name nomenclature, and there may be other unforeseen circumstances.

There are also those who opposing view for the single name nomenclature. Gams-Jaklitsch and 77 academicians (2011) are the examples for the opposing view to Amsterdam Declaration (Hawksworth et al., 2011). Gams proposed views opposing the single name nomenclature in another study published in 2016.

Fungal morphology, colonies and microscopic characteristics will continue to be used, but they will not be completely abandoned, although their importance will be reduced. Increasing molecular studies from the end of the 1980's would become even more important and would be standard for fungal taxonomy, despite the slow progress of sequencing. In addition to the gene regions used for fungal species (ITS1-ITS2-Internal Transcribed Spacer, Calmodulin, β -tubulin etc), new gene regions can be studied in the future. Indeed, Crous et al. (2014) and Demirel (2016) stated that LSU (28S rDNA) can be used for phylogenetic analysis. Factors such as the high cost of molecular studies compared to traditional morphological studies, the inadequacy or inadequacy of each mycology laboratory, the lack of trained staff and the difficulties in finding resources for the studies have the effect of lowering the rate of sequencing of fungal species. Over time, direct DNA uptake (metagenomic) may be increased from various habitats (eg, air environment) without conventional isolation methods. For example, as reported by Hibbet and Taylor (2013), although only 100 species of *Archaeorhizomycetes* have been reported so far, only 1 (*Archaeorhizomyces finlayi*) has been reported by culturing traditional methods; others were studied by metagenomic methods. In spite of any difficulties, it is expected that a standard will be formed in the future with series analyzes of fungal species. Ideally, morphological, colonial, anatomical and microscopic characteristics and molecular studies are performed together.

Despite some of the counter-arguments and some of the problems encountered, was there a need to change the system implemented since 1905? Fungal taxonomy is very variable. According to the new information obtained, the characters used in the fungal taxonomy also change. Dual system could sometimes be incomprehensible for those who did not expert on fungal taxonomy. As



mycology science is related to many scientific disciplines, researchers who do not have any knowledge about fungal

taxonomy also have to deal with mycology. The fact that a fungal species has two names can cause confusion.

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