

Full Length Research Paper

Ecological distribution, diversity and use of the genus *Digitaria* Haller (Poaceae) in Senegal

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Received 22 September, 2017; Accepted 19 December, 2018

The genus *Digitaria* Haller is one of the most important of grass flora of Senegal by both its specific richness and the socio-economic value of its species. Despite this importance, no studies have been done specifically on these species. This study aims, therefore, to document the diversity, distribution, ecology and usefulness of the genus of such species for raising public awareness about botanical, ecological distribution, and status of such species and their uses in Senegal. Data collection approach was based on field work conducted in Senegal that has allowed the preparation of distribution maps of species related to ecological factors such as climate, vegetation and soil coupled with a literature review used to determine the use of species. Consequently, literature accessed has revealed that various species of *Digitaria* exist and they consist mainly of weeds, forage or food crops. *Digitaria* spp. has a wider distribution with some species having a broader distribution whereas others are restricted to some African regions. They are generally encountered throughout the tropics including in rainforests, savannas and steppes; wherein soils are sandy and acidic types. In Senegal, most of the species are found in the south under a Sudano-Sahelian zone, growing on almost all vegetation and soil types. This study, which is a contribution to the improvement and preservation of the living environment of these species, is an important step for the facilitation of any conservation action. It also encourages a greater appreciation of the value of these species, which are potential sources of genes from *Digitaria exilis*, the cultivated species.

Key words: *Digitaria*, climatic zones, vegetation types, soil types, conservation, Senegal.

INTRODUCTION

The genus *Digitaria* Haller comprises ca. 220 species distributed in tropical, subtropical, and temperate areas worldwide (Vega et al., 2009; Boonsuk et al., 2014; Okanume et al., 2014; Ngom et al., 2016; Lo Medico et

al., 2017). In tropical Africa, accessible data mentions about sixty species (Robyns, 1931). However, knowledge on current diversity of the genus in this region, including Senegal, is poorly available. In Senegal, the genus

Digitaria is among the most important groups of Poaceae in terms of socio-economic value of the species. It is found in a range of habitats but seems to be most diverse in open areas or grasslands (Boonsuk et al., 2016). Crabgrass species grow in disturbed areas, particularly in gardens and cultivated fields, and are seldom observed in natural veld (Hugo, 2014).

The socio-economic importance of *Digitaria*' species is particularly in their uses as source of human food (Koroch et al., 2013; Ouedraogo et al., 2015; Barnaud et al., 2017), fodder (Beck et al., 2017; Harun et al., 2017) and in pharmacopoeia (Poilecot, 1995, 1999; Pare et al., 2016). Despite the usefulness of this genus, little research has been directed towards studying the botanical and geographical distribution of the genus or of the species in Senegal. The Sudano-Sahelian region has undergone land cover change and land use changes driven by anthropogenic pressures over recent years. The negative impacts of these anthropogenic factors and precarious climatic conditions balance the exploitation and regeneration of resources over time and space, which results in a gradual disappearance of land cover. In Senegal, studies on the distribution of crabgrass are out of date (Berhaut, 1967; Vanden, 1991) and some species such as *Digitaria aristulata*, *Digitaria gentilis* and *Digitaria patagiata* are rare, endemic and endangered, respectively (USAID/Senegal, 2008; Ngom et al., 2016). Therefore, gathering such data could be crucial to determining the current geographical distribution of each species of that genus according to environmental factors.

This paper aims at providing updated knowledge on the botanical and geographical distribution of 19 species of *Digitaria* in Senegal according to the climatic zones, types of vegetation and soil, and to document the usefulness of that species based on available literature on their social and economic importance as a source of animal feed and human consumption.

MATERIALS AND METHODS

Diversity, distribution and ecology of species in Senegal

Senegal, a Western African country, belongs to the Upper Sahelian region. Its geographical position, in a transition zone between the North and the South rainforest, provides to the country a rich ecosystem of high biological diversity (MEPN, 1997). Among the species richness of that ecosystem includes the genus *Digitaria*. The species studied were *D. acuminatissima*, *D. argillacea*, *D. aristulata*, *D. ciliaris*, *D. debilis*, *D. delicatula*, *D. diagonalis*, *D. exilis*, *D. gayana*, *D. gentilis*, *D. horizontalis*, *D. leptorhachis*, *D. longiflora*, *D. nuda*, *D. patagiata*, *D. perrottetii*, *D. sanguinalis*, *D. ternata* and *D. velutina*. For each species studied, the geographical coordinates of herbarium collections (all species studied) of the Herbaria IFAN and DAKAR (Cheikh Anta Diop University) were

recorded. These data were supplemented by those of the Global Biodiversity Information Facility (GBIF) database (all species studied) and those from our collection (specimens of *D. ciliaris*, *D. exilis*, *D. horizontalis*, *D. longiflora* and *D. perrottetii* collected in the regions of Dakar and Ziguinchor). Field work has allowed the collection of data on the species such as *D. acuminatissima*, *D. gentilis* and *D. sanguinalis* in Senegal.

However, geographical coordinates of those species were not initially available in the country's database. As a result, geographical coordinates of these species have been taken into account in the analysis of the country's species distribution maps. In this study, three ecological factors were documented: i) the climate which remains one of the most important factors influencing species distribution, ii) vegetation, and iii) soil. In the analyses applied here, the definition of global climate zones characterizing the distribution of *Digitaria* species was based on the Köppen (1900) classification. Maps of major vegetation and world types of soil were provided by WWF and FAO, respectively. In Senegal, the climate zone map has already been defined by Mbow (2009); whereas, the characteristics of the types of vegetation and soil were provided by the Ecological Monitoring Center (Centre de Suivi Ecologique, 2007).

A georeferencing approach based on cards selection with the QGIS software (version 1.5.0 Tethys, 2010) was used to analyse the species distribution. Such approach has allowed assigning geographic coordinates to these cards in the form of an image file. The projection of geographical coordinates of different samples from geo-referenced maps has allowed the designation of species distribution areas.

Usefulness of species

For ethnobotanical study, information gathered comes from a literature review. Data on different uses of species was obtained from: floras (Vanden, 1991; van der Zon, 1992; Poilecot, 1995, 1999); botanical and agronomy textbooks (Kleinschmidt and Johnson, 1977; Muenscher, 1980; Merlier et al., 1982; Akobundu and Agyakwa, 1989; Le Bourgeois and Merlier 1995; Wilson et al., 1995; Halvorson and Guertin, 2003; Brink and Belay, 2006) and other types of scientific documents (Robyns, 1931; Obizoba and Anyinka, 1994; Lepschi and Macfarlane, 1997; Quattrocchi, 2006).

RESULTS AND DISCUSSION

Diversity, distribution and ecology of species

From this study, it appears that 19 species of *Digitaria* studied are spread over all continents and mainly in tropical and subtropical regions (Figure 1). The wide distribution of these species is in line with those highlighted by Poilecot (1999), Vega and Rúgolo de Agrasar (2002a), and Adoukonou-Sagbadja et al. (2006). Some of these taxa such as *D. acuminatissima*, *D. aristulata*, *D. delicatula*, *D. gayana*, *D. gentilis*, *D. leptorhachis*, *D. patagiata* and *D. perrottetii* are strictly encountered in Africa. Such African distribution of the species has already been indicated by the following

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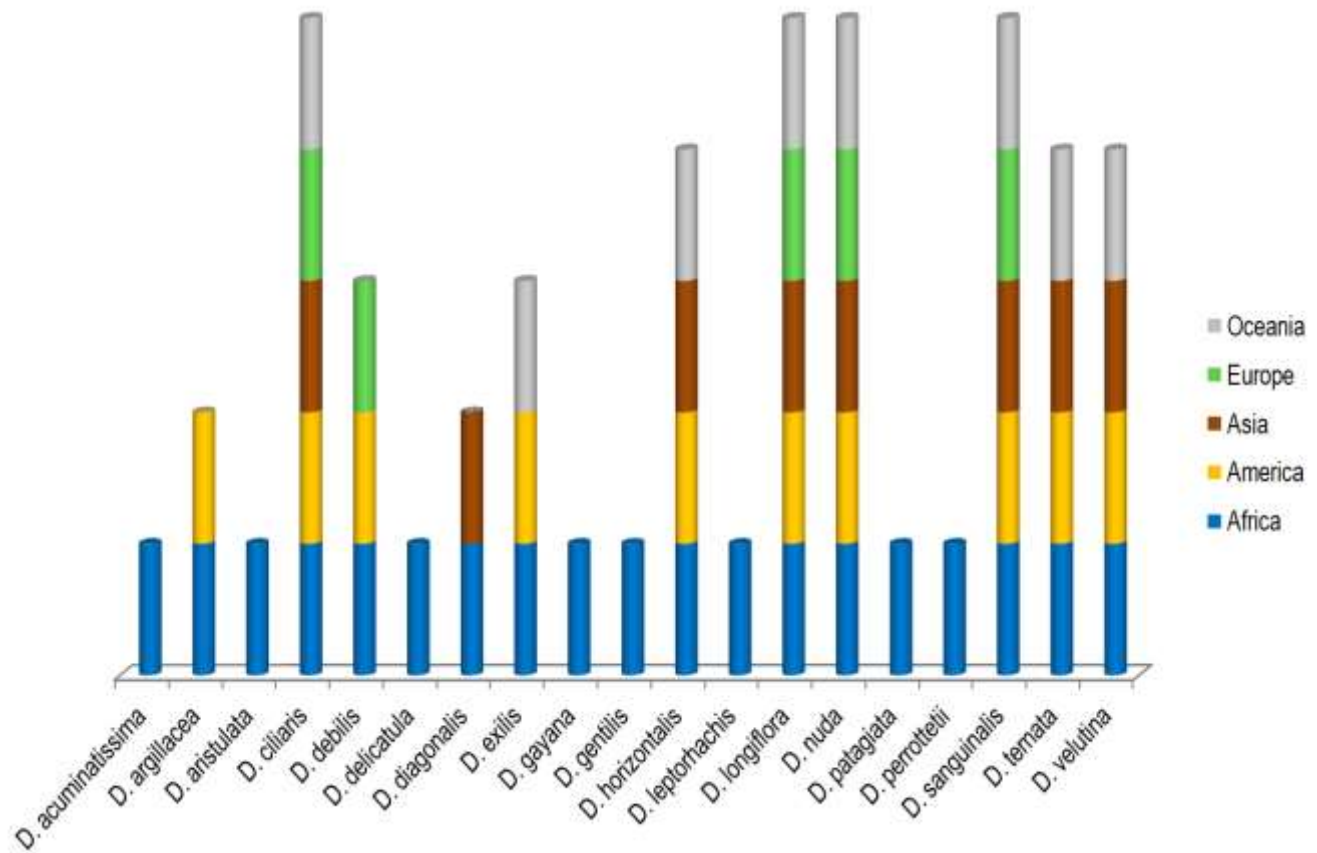


Figure 1. Continents where species of the genus *Digitaria* are encountered.

scholars (Vanden, 1991; van der Zon, 1992; Poilecot, 1995, 1999). On the contrary, other species have wider distribution area (throughout the five continents), such as: *D. ciliaris*, *D. longiflora*, *D. nuda* and *D. sanguinalis*.

In line with the previous result, the continental distribution of *D. ciliaris* has already been highlighted by Poilecot (1995) as well as the distribution of *D. longiflora* distribution. Vanden (1991) reported that *D. longiflora* is mostly distributed in the tropics.

Regarding the geographical distribution of *D. nuda*, the studies of van der Zon (1992) and Poilecot (1999) have reported that such species are encountered in tropical regions including Africa, Mauritius, Brazil, Indonesia, etc. Similarly, *D. sanguinalis* is widely encountered in tropical and warm temperate regions (Clayton, 1989).

The type of climate represents the first factor influencing the species' distribution. There is a worldwide distribution of the species according to the climatic zones (Figure 2), vegetation types (Figure 3) and soil types (Figure 4). The distribution of such species is not accidental. In the African continent, the distribution of species of the genus *Digitaria* is remarkably encountered in tropical rainforests, savannas and steppes; and wherein soils are mostly sandy and acid. Such species

tend to thrive when living under arid climatic zones characterized by a deficiency in rainfall, and in the polar zone or tundra type of areas, wherein the average and annual temperature tend to be below zero. It can be argued that the species of the genus *Digitaria* has developed a substantial ability to adapt to highly variable environmental conditions given that in polar areas often with bare substratum, and formed with ice and rocks; they are not often encountered.

Figures 5 to 8 show the distribution of the genus *Digitaria* according to the climatic zones, vegetation types, and soil types, respectively, covered by each species in Senegal.

In terms of species richness, the Sudan region tends to be more represented. In that region alone, 12 species have been inventoried so far, namely: *D. argillacea*, *D. aristulata*, *D. ciliaris*, *D. diagonalis*, *D. gayana*, *D. nuda*, *D. delicatula*, *D. exilis*, *D. gentilis*, *D. horizontalis*, *D. longiflora* and *D. ternata*. On the contrary, the Sudano-Saharan zone tends to be the geographical area wherein the richness of the species is the lowest, with five species inventoried so far, such as: *D. aristulata*, *D. ciliaris*, *D. horizontalis*, *D. longiflora* and *D. velutina*.

Although the specific richness is independent from the

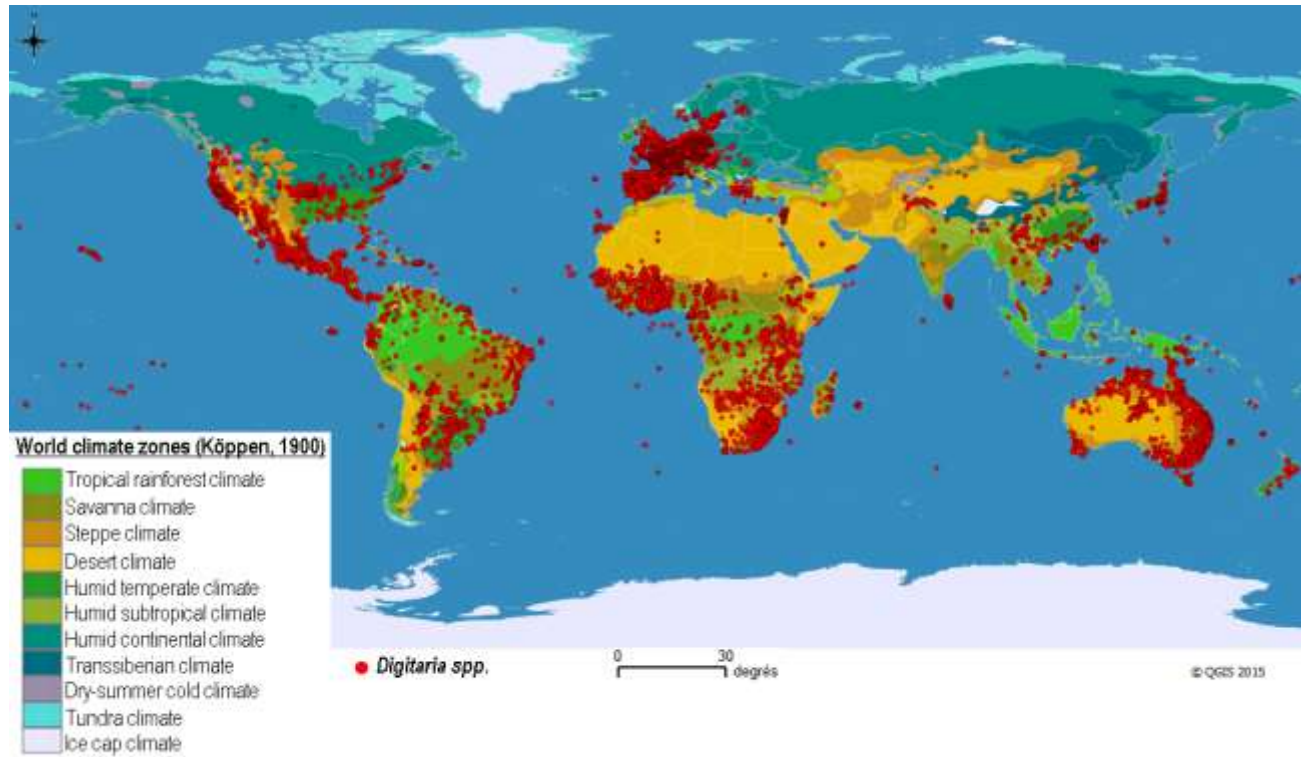


Figure 2. Species' distribution according to the climatic zones in the world.
Source: Wikimedia Commons.

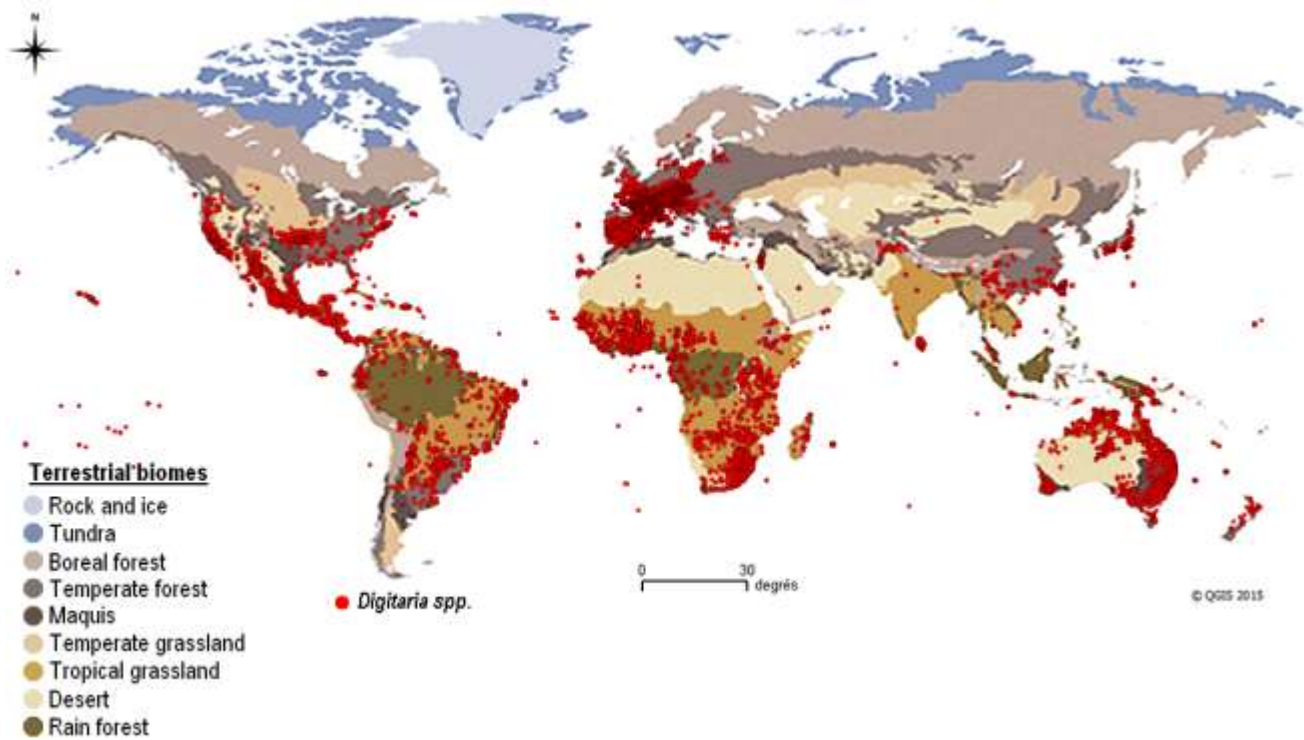


Figure 3. Species' distribution according to the vegetation types in world.
Source: QA International.

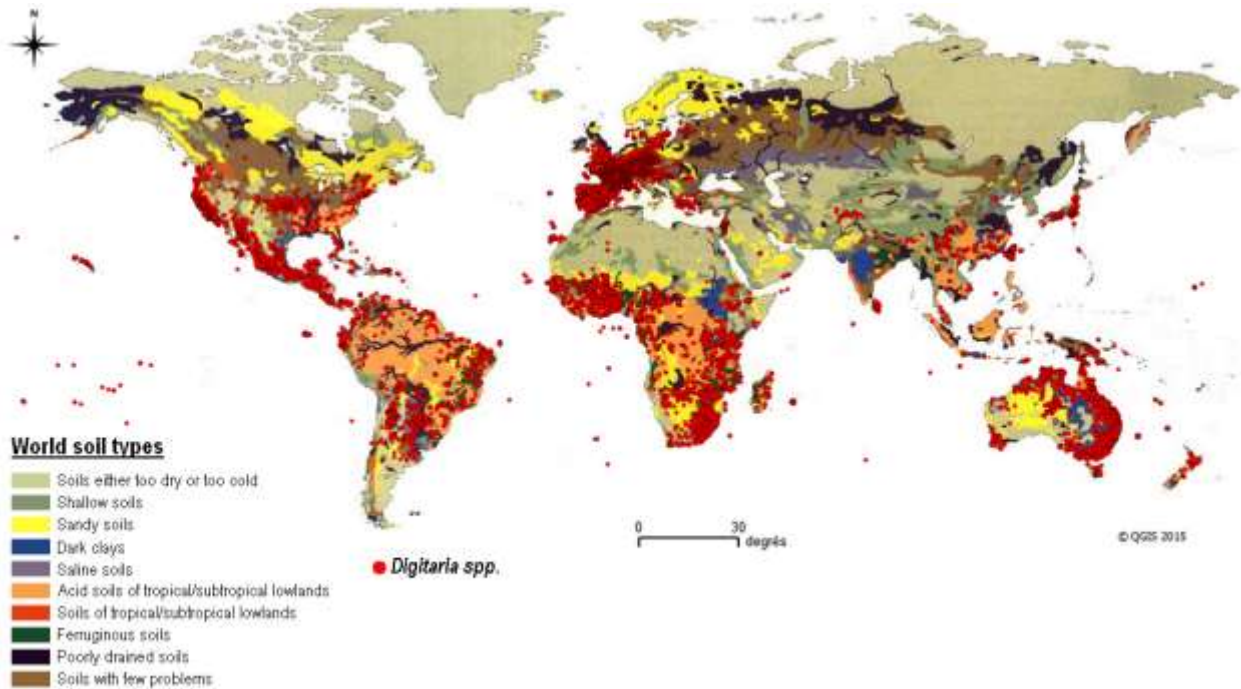


Figure 4. Species' distribution according to the soil types in the world.
Source: FAO.

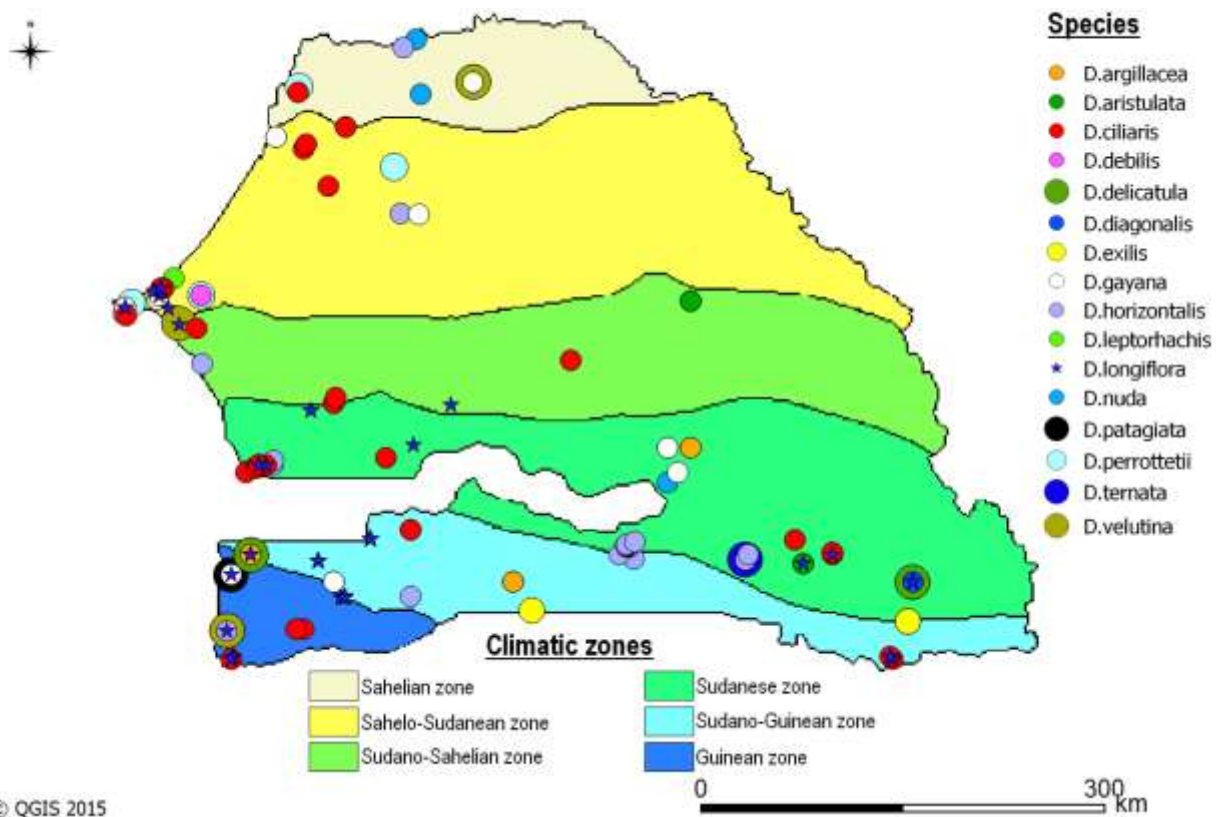


Figure 5. Species' distribution according to the climatic zones in Senegal.
Source: Mbow, 2009.

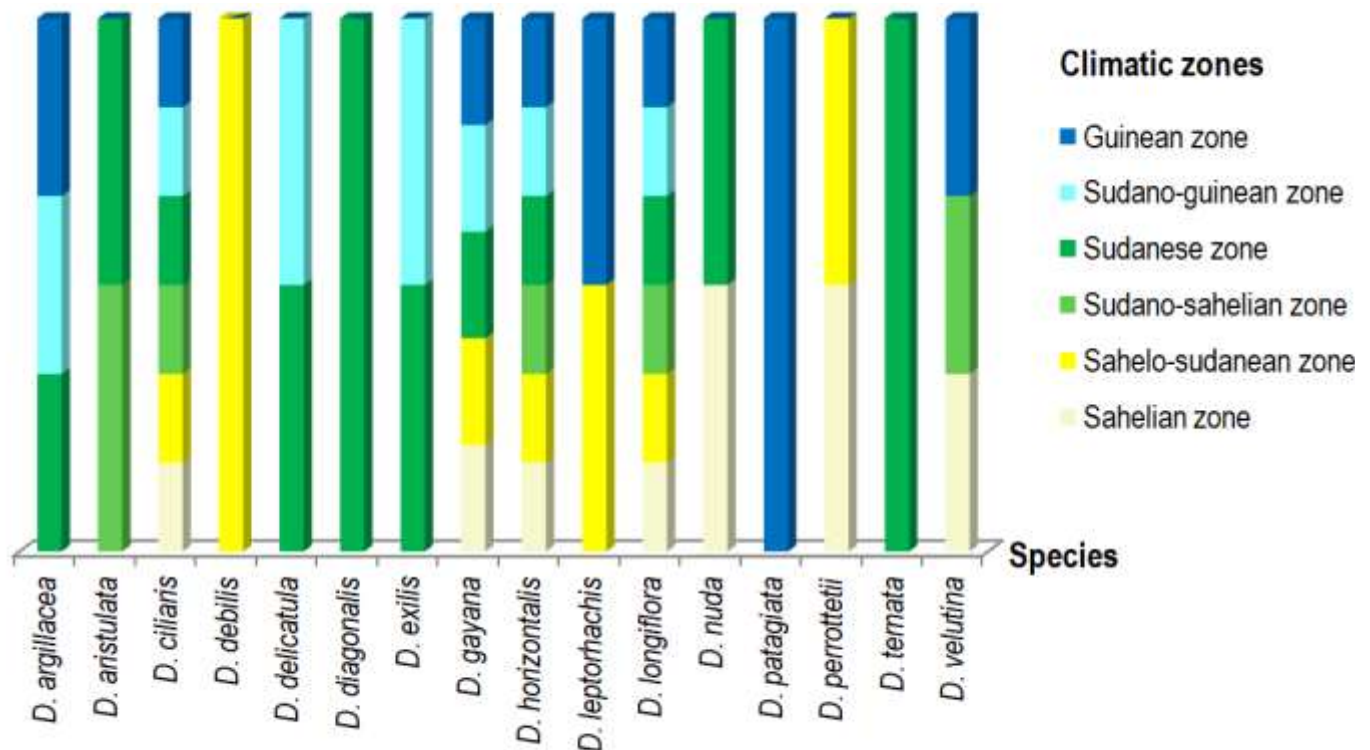


Figure 6. Climatic zones covered by each species encountered in Senegal.

North-South climatic gradient, it is important to note, however, that 15 out of the 19 species found in Senegal (including *D. acuminatissima*, which is not shown on the maps) are encountered in the Guinean areas, Sudano-Guinean and Southern part of the Sudan area. It could be argued that in those geographical and ecological areas, most of the species of *Digitaria* tend to encounter favorable environmental conditions for their growth.

In Africa in general, and in Senegal in particular, although none of the six climate zones is characterized by a particular flora of *Digitaria*, it is remarkable to note that some species have a wide distribution area (Figure 6). That is the case with *D. ciliaris*, *D. horizontalis* and *D. longiflora* that cover all the climatic zones in Senegal. In the case of *D. longiflora*, additional data from non-georeferenced samples of the species confirms its presence in this area, especially in the Senegal River region (Berhaut 5420).

Conversely, other species have a rather narrow distribution in the African continent as is the case of *D. diagonalis*, *D. ternata* (Sudanese zone), *D. patagiata* (Guinean zone), *D. argillacea*, *D. exilis* and *D. delicatula* that appear to be Sudano-Guinean species. Specimens of *D. gentilis* have been inventoried in the Sudan region (National Park of Saloum Delta) by Lykke et al. (1994). But, these specimens (Lykke et al. 309 and Lykke et al. 323) have been confused with *D. longiflora*. Since 1930, *D. gentilis* tends to be only encountered in the Sudano-

Sahelian region by Trochain (Trochain 570), especially along the backwater of Hann in Dakar.

On the other hand, *D. perrottetii* represents the species that has a Sahelian affinity, because this species tends to be encountered in the Sahelian and Sahelo-Sudanean. *D. aristulata* has a Sudano-Sahelian affinity, because it was inventoried in the Sahel and Mali (Vanden, 1991). Although the area of distribution of *D. acuminatissima* and *D. sanguinalis* is not shown on the distribution map, however, these species tend to have a limited distribution, especially encountered broadly in the south (Vanden, 1991) and in Dakar (Berhaut 2824), respectively.

Although many species are also encountered both in the north and in the south of the country, however they are not reported in all climate zones. The presence of species such as *D. debilis*, *D. gayana*, *D. leptorhachis*, *D. nuda* and *D. velutina* in geographical opposite zones (North and South) may tend to reveal their lack of affinity with regards to the given type of climate. On the contrary, they are species that are only encountered in the Sudano-Sahelian region, such as *D. debilis*. However, the geographical area covered by such species tends to be important, because it was found in Sine-Saloum, in Lower Casamance (Vanden, 1991) and in Thies (Berhaut 1080, 2784), respectively.

In Senegal, for example, the different climatic zones of the country are characterized by typical vegetation. This

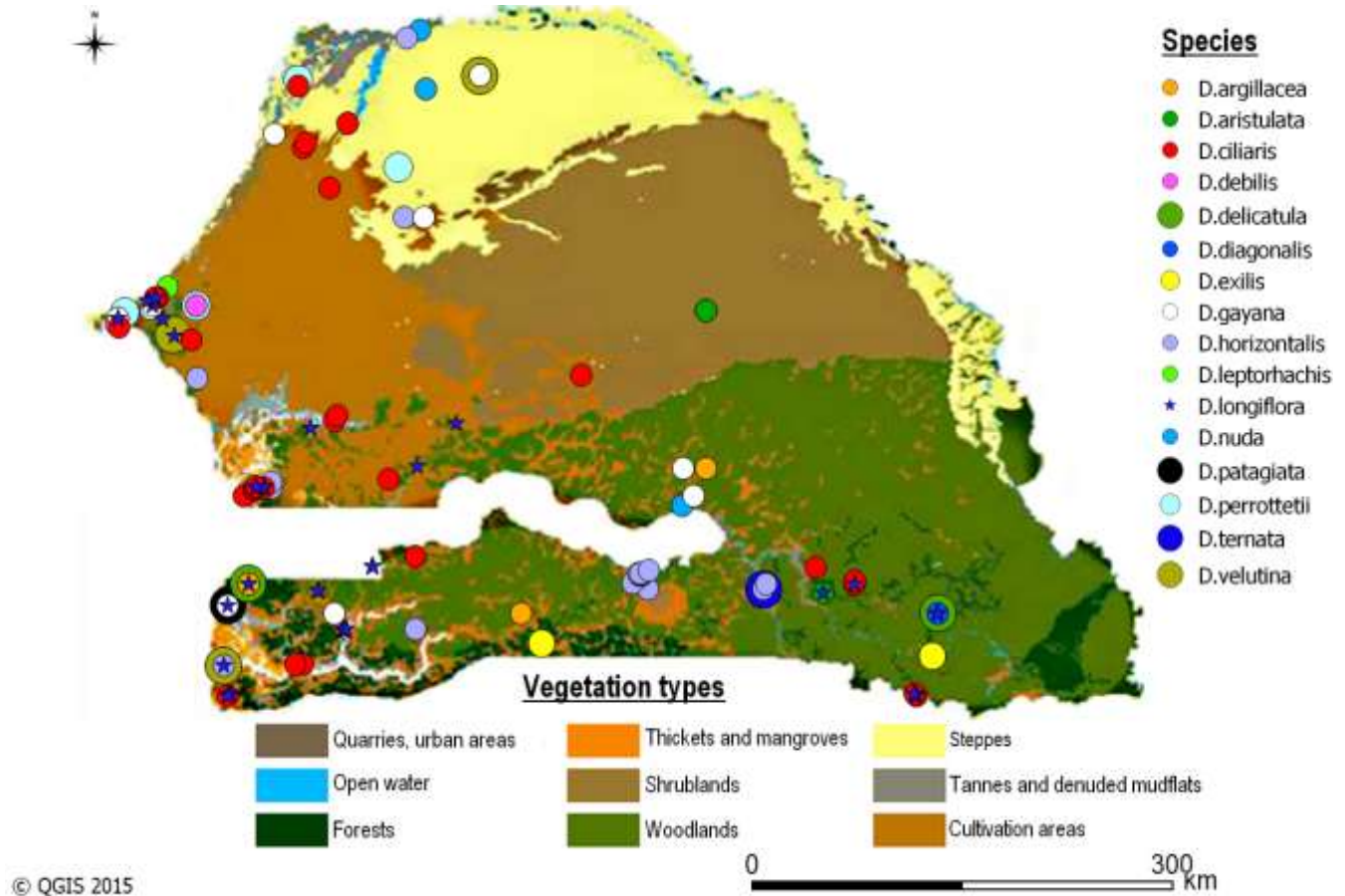


Figure 7. Species distribution according to the vegetation types in Senegal. Source: CSE, 2007.

means that the Sahelian zone is generally composed of steppe-type vegetation; while the Sudanean and Guinean zones are characterized by woodlands and forest-type vegetation. According to the results of the study, the species of the genus *Digitaria* are reported in almost all types of vegetation and soil types in Senegal (Figures 7 and 8). Thus, such species tend to grow on semi-arid (red-brown), ferruginous, ferralitic, hydromorphic, little evolved soils, or on lithosol, regosol or mudflat soil types. Such soils are usually covered by a diversified type of vegetation such as steppes, savannas (wooded and shrub) and forests. If, in their entity, *Digitaria*'s species support a wide range of environmental conditions, it is still worth mentioning that some have outstanding features. Whether they are present in all climate zones or not, these species are encountered both in arid areas where the vegetation is steppe (the North) and wetlands which consist largely of forests and woodlands (south). That is the case of *D. ciliaris*, *D. gayana*, *D. horizontalis*, *D. longiflora*, *D. nuda* and *D. velutina*. With the exception of *D. nuda* and *D. velutina*, these species grow on a variety of soils that spread mainly from North to South, in semiarid soils formed of dunes, ferruginous and ferralitic

soils. These are characteristics of the regions with Guinean or Sudano-Guinean climate (Michel, 1973).

Uses of species

Table 1 shows the worldwide distribution and usefulness of different species of the genus *Digitaria*. As shown in Table 1, the distribution of the *Digitaria* species is wider, because the species have been inventoried throughout the five continents of the world. As expected, usages of the species are of great socio-economic value. Weeds are often source of damage to some crops as it is the case for *D. ciliaris*, *D. horizontalis*, *D. longiflora*, *D. nuda*, etc. (Wiersema et al., 2013). Species such as *D. ciliaris* cause severe infestations and damage to growth of corn (Bassene, 2014) while *D. nuda* has been identified as a troublesome weed in West African countries especially in sugarcane production (Chikoye et al., 2000; Dias et al., 2005) and in crop fields in South Africa, and other countries to the north in Africa (Hugo et al., 2014a; Hugo et al., 2014b).

Despite the damaging role played by weeds in crop

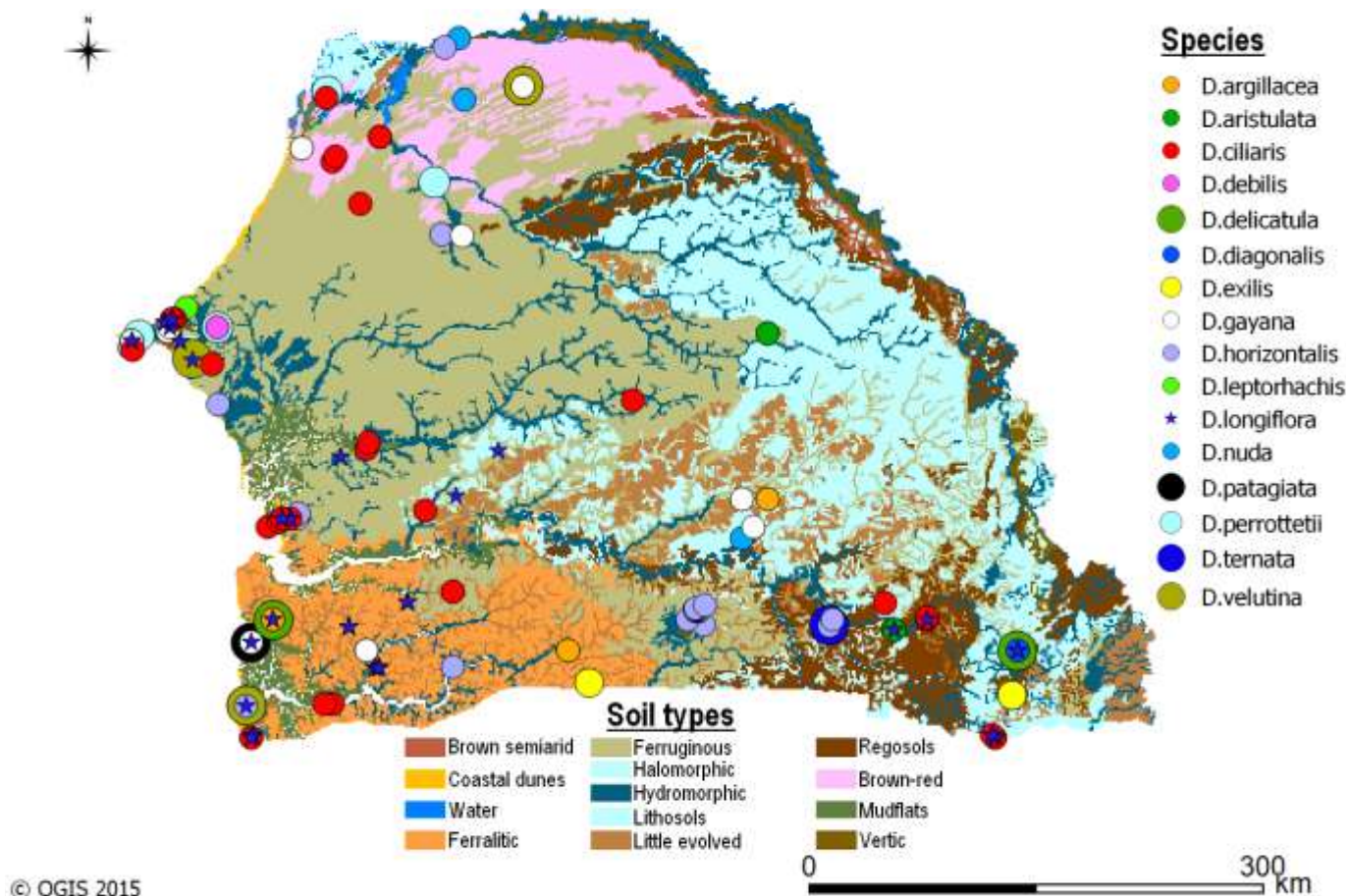


Figure 8. Species distribution according to the soil types in Senegal. Source: CSE, 2007.

growth, such weeds however are often less beneficial to human as a source of food (36.84%), than to livestock as source of feed (68.42%). Other key roles played by weeds include soil conservation. In southern Senegal for example, the only cultivated species of *Digitaria* is *D. exilis*. In the Sahel region, other species are increasingly more consumed; especially in time of environmental crises such as famine, crop failure. This is the case of the species such as *D. ciliaris*, *D. debilis*, *D. horizontalis* (Poilecot, 1999; Sene, 2000; Brink and Belay, 2006; Diarra et al., 2016), *D. longiflora*, *D. nuda* (Quattrocchi, 2006) and *D. sanguinalis* (Portères, 1955; Brink and Belay, 2006). As a result, they tend to play a safety role function, especially in time of household crises. In the Sahel region, the safety role function tends to be widely acknowledged by policy makers.

In traditional medicines such as pharmacopeia, about 15.79% of the species are used for that purpose. In Africa, grain of *D. exilis* is highly used for its therapeutic values (Obizoba and Anyinka, 1994; Poilecot, 1995; Ibrahim and Saidu, 2017). In Togolese traditional medicine for example, the powder obtained from calcined

leafy stems of *D. horizontalis* is used against vomiting in children (Poilecot, 1995, 1999). In Senegal, decoctions of *D. leptorhachis* are used to bathe the children, making them stronger (Poilecot, 1995, 1999). Finally, 10.53% of species are used for the creation of lawns as is the case for *D. ciliaris* and *D. horizontalis*; while 5.26% of the species tend to be used as ornamental plants. That is the case of *D. longiflora*.

Conclusion

The worldwide distribution of the 19 *Digitaria*'s species studied according to climatic zones, vegetation types, and soil types show that *Digitaria*'s species are found in a wide range of environmental conditions.

The distribution of *Digitaria* species in relation to climate zones, vegetation types and soil types in Senegal indicates that the species, taken as a whole, occupy all of the Senegalese territory; and therefore, very varied environments. However, most of them are found in the south of the country where the environmental conditions

Table 1. Worldwide distribution and usefulness of *Digitaria* species.

<i>Digitaria</i> species	Worldwide distribution of species	Uses of species
<i>D. acuminatissima</i>	Africa ^{1, 2}	weed ⁶ , fodder ¹⁷
<i>D. argillacea</i>	Africa ^{1, 2} , America ²	weed ^{6, 18} , fodder ⁴
<i>D. aristulata</i>	Africa ^{1, 2}	-
<i>D. ciliaris</i>	Africa ^{1, 2} , America ² , Asia ² , Europe ² , Oceania ²	weed ^{6, 7, 8, 9, 10} , food ⁶ , fodder ^{5, 6, 7, 8, 9, 10} , pelouse ⁵
<i>D. debilis</i>	Africa ^{1, 2} , America ² , Europe ²	food ^{5, 20} , fodder ⁵
<i>D. delicatula</i>	Africa ^{1, 2}	fodder ⁶
<i>D. diagonalis</i>	Africa ^{1, 2} , Asia ²	fodder ^{6, 11}
<i>D. exilis</i>	Africa ^{1, 2} , America ² , Oceania ²	food ⁶ , weed ⁶ , fodder ^{4, 5, 6} , pharmacopoeia ¹²
<i>D. gayana</i>	Africa ^{1, 2}	weed ⁶ , fodder ^{4, 5}
<i>D. gentilis</i>	Africa ^{1, 2}	-
<i>D. horizontalis</i>	Africa ^{1, 2} , America ² , Asia ² , Oceania ²	weed ^{6, 13, 18, 19} , food ³ , fodder ^{3, 4, 5, 6, 17} , pelouse ^{4, 5} , pharmacopoeia ^{4, 5}
<i>D. leptorhachis</i>	Africa ^{1, 2}	weed ⁶ , fodder ^{3, 4, 5, 6} , pharmacopoeia ^{4, 5}
<i>D. longiflora</i>	Africa ^{1, 2} , America ² , Asia ² , Europe ² , Oceania ²	weed ⁶ , food ⁶ , fodder ^{3, 6, 17} , ornamental ⁶
<i>D. nuda</i>	Africa ^{1, 2} , America ² , Asia ² , Europe ² , Oceania ²	weed ⁶ , food ⁶ , fodder ⁶
<i>D. patagiata</i>	Africa ^{1, 2}	weed ⁶
<i>D. perrottetii</i>	Africa ^{1, 2}	-
<i>D. sanguinalis</i>	Africa ^{1, 2} , America ² , Asia ² , Europe ² , Oceania ²	food ²⁰ , weed ^{14, 15, 16}
<i>D. ternata</i>	Africa ^{1, 2} , America ² , Asia ² , Oceania ²	weed ⁴ , fodder ^{4, 17}
<i>D. velutina</i>	Africa ^{1, 2} , America ² , Asia ² , Oceania ²	weed ¹³

1 : GBIF ; 2 : Herbaria (DAKAR, IFAN) ; 3 : Vanden, 1991 ; 4 : Poilecot, 1995 ; 5 : Poilecot, 1999 ; 6 : Quattrocchi, 2006 ; 7 : Kleinschmidt and Johnson, 1977 ; 8 : Muenscher, 1980 ; 9 : Wilson et al., 1995 ; 10 : Lepschi et Macfarlane, 1997 ; 11 : van der Zon, 1992 ; 12 : Obizoba and Anyinka, 1994 ; 13 : Merlier et al., 1982 ; 14 : Robinson, 1969 ; 15 : Halvorson and Guertin, 2003 ; 16 : Brink and Belay, 2006 ; 17 : Robyns, 1931 ; 18 : Le Bourgeois and Merlier, 1995 ; 19 : Akobundu and Agyakwa, 1989 ; 20 : Portères, 1955.

are more favorable.

The usefulness of such species as a source of food for local populations and feed for animals worldwide is notable, especially with a species focus in Senegal. *D. exilis* or white fonio is a good example, because it is the only cultivated species of the genus in the south of the country and contributes to food security.

This study provides important tools for enhancing the conservation and wise use of *Digitaria* species based on the knowledge of their ecology and biogeographic distribution, especially those that are endemic (*D. gentilis*) or endangered (*D. aristulata* and *D. patagiata*). The information reported here can also serve to strengthen all of the conservation actions in wise use of natural resources, and could be an important step in the process leading to better management of wild species that could potentially be useful to improve crop production.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors thank the West Africa Agricultural

Productivity Program (WAAPP/PPAAO 2A) for funding these research activities along with the curators of DAKAR and IFAN Herbaria for providing plant materials.

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