Digitaria exilis

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Digitaria exilis, referred to as **findi** in areas of Africa, such as The Gambia,[a][3] with English common names **white fonio**, **fonio millet**, and **hungry rice** or **acha rice**,[4] is a grass species. It is the most important of a diverse group of wild and domesticated *Digitaria* species known as fonio that are harvested in the savannas of West Africa. The grains are very small. It has potential to improve nutrition, boost food security, foster rural development and support sustainable use of the land.

The name (borrowed by English from French) is from Wolof *foño*.[5]

Fonio has continued to be important locally because it is both nutritious and one of the world's fastest growing cereals, reaching maturity in as little as six to eight weeks. It is a crop that can be relied on in semi-arid areas with poor soils, where rains are brief and unreliable. The grains are used in porridge and couscous, for bread, and for beer.

The small grains make it difficult and time-consuming to remove the husk. Traditional methods include pounding it in a mortar with sand (then separating the grains and sand) or "popping" it over a flame and then pounding it (which yields a toasted color grain; this technique is used among the Akposso). The invention of a simple fonio husking machine offers an easier mechanical way to dehusk.

The genetic diversity of *Digitaria exilis* varies from region to region in Africa. For example, not much genetic diversity was detected among the domesticated *Digitaria exilis* landraces from Mali.[6] In contrast, large levels of genetic diversity were detected among the domesticated *Digitaria* exilis landraces of the Upper Niger River Basin of West Africa.[7] The many different landraces of Digitaria exilis are affected differently by the various processing methods.[8]

Contents

Digitaria exilis	
	
Scientific classification	
Kingdom:	Plantae
(unranked):	Angiosperms
(unranked):	Monocots
(unranked):	Commelinids
Order:	Poales
Family:	Poaceae
Genus:	*Digitaria*
Species:	***D. exilis***
Binomial name	
Digitaria exilis (Kippist) Stapf	
Synonyms[1]	
Panicum exile (Kippist) A.Chev. nom. illeg. *Paspalum exile* Kippist *Syntherisma exile* (Kippist) Newbold	

Description

The fonio is an annual, erect herbaceous plant which reaches stature heights from 30 to 80 centimeters. The ears consist of two to five narrow part ears, which are up to 15 centimeters long. The spikelets comprise a sterile flower and a fertile flower, the latter of which gives rise to the fonio grain. The grain is a caryopsis, which remains surrounded by glumes and husks. Its size is very small, only 1.5 mm (around 2000 seeds to 1 gram).The colour ranges from white, yellow and purple. Fonio mature faster than all other cereals. Some varieties can already be harvested 42–56 days after sowing. Other ripen more slowly, usually in 165–180 days.[9]

Origin and regions cultivation

Fonio is one of the ancient African crops, possibly the oldest West African crop as its cultivation seems to have started about 7,000 years ago.[10] The first references to Fonio as food are reported from the mid-14th century.[9]

Significant cultivation is in West Africa from Chad to Cape Verde, South Mali, in western Burkina Faso, eastern Senegal, northern Guinea, in north-eastern Nigeria as well as in the south of Niger, where the plant supplies the staple food for several million people. In some regions of Mali, Burkina Faso, Guinea and Nigeria, Fonio is the most important or one of the main cereals. The White Fonio has its main growing region in the highland plateaus of Nigeria, where it is called Acha. The second Fonio-species Iburu or Black Fonio is limited on the Jos-Bauchi Plateau in Nigeria and the northern regions of Togo and Benin.[9]

Fonio is grown in parts of the Dominican Republic, where it has already brought in 1500 from West Africa, firstly only grew as a weed, but it is also cultivated again lately.[11]

Production and cultivation area (2013)

Country	Production(t)	Area(ha)
Guinea	429 000	300 000
Nigeria	90 000	165 000
Mali	22 000	34 000
Burkina Faso	20 000	25 000
Ivory Coast	17 000	15 000
Niger	6 000	11 000
Benin	1 300	1 900
Senegal	1 000	1 500
Guinea Bissau	700	600
Total	587 000	554 000

source:[12]

Yield

More than 550 000 ha of fonio are grown each year in West Africa and the production runs at 587 000 t. Yields are relatively stable, the yield average is currently 1t/ha. In the peripheral regions the yields are less than 500 kilograms and drop when in very poor soils down to 150 to 200 kilograms.[9]

Climate and soil requirements

Fonio is cultivated in West Africa under tropical climate, with a pronounced dry season, temperatures between 25-30 °C and annual rainfalls of 600 to 1200 mm. Nevertheless, Fonio is also grown in higher altitude: over 1000 m, with higher annual rainfalls (1200 to 1500 mm) and colder temperatures (15-25°). Fonio has a well developed root system, which can reach more than one meter depth in the soil. This root system explains the good performance of the plant during the dry season and its adaptation to poor and low fertility soils. Fonio is mainly grown on sandy soils, but can also grow on rocky soils. It also thrives on acidic clay soils with a high aluminium content. On heavy soils, most varieties thrive badly. This crop is low demanding and can cope with unfavourable climate and soil conditions.[9]

Field management

The most works are done by hand.[9]

Before sowing

The main works to do before sowing are the cleaning of the field and ploughing. Sometimes animals are used for ploughing or a *daba* is utilized to do a superficial scratching.[9]

Sowing and upkeep

The sowing time starts with the first rainfalls. This can vary depending on the variety and the geographical area of cultivation. The grains used for sowing are the best grains kept from the precedent harvest and are sown by hand (broadcast seeding). Sometimes the seeds are mixed with sand to have a more homogenous repartition on the soil. The seeds remain on the surface, so successive harrowing by hand or with the daba is needed to bury them slightly in the soil. Normally 30–40 kg/ha of seeds are used, but sometimes more than 70 kg/ha are sown, in order to control weeds at time of emergence. For germination and emergence a temperature of 30 °C is optimal. The germination and growth is rapid, and for the upkeep of the crop only weeding is needed.[9]

Harvest and post-harvest processing

Harvesting is mostly still done by hand. As soon as the grains reach maturity, usually during July or August, men cut the fonio with sickles whilst woman and children collect them to sheaves. A facilitation is the use of a motor-driven mower. They have to be stored in a dry and airy space to prevent mould formation. During the dry season the sheaves are piled to big stacks in the sun to dry them completely. Threshing is done as well manually. Tractor-driven threshers are rarely used because of the higher costs and the higher loss of the small grains. The grains are stored loosely in storehouses. Before consumption the spelts have to be removed, they are not digestable. This process is traditionally done by women in mortars. After the fifth decortication the fonio is called "whitened". Adhering grit and sand is washed of with the help of gourds. This process demands very skilled woman and up to 10 liters clean water for one kilogram of fonio.[9]

Instead of the labour-intensive manual processing machines could be used. There has been much effort for a long time to obtain efficient machines. The same threshing-machine used for rice could be adapted with some technical modification for fonio. Because of the high cost and performance of such machines they have to be

operated by multiple villages to be economically efficient. To clean the threshed seeds winnowing machines or rotational sieves could be used. The CIRAD developed a decortication machine of the GMBF type especially for fonio.[9][13]

Digitaria exilis is a crop that has not been pursued for domestication worldwide, but actually has many qualities that make it a good crop candidate. *Digitaria exilis* is an annual[14] plant that has a C4 metabolism and is medium in height.[15] It can be planted alone or among other crops in the marginal land. Farmers value how quickly *Digitaria exilis* comes to maturation. In as little as six to eight weeks the crop reaches maturity.[16]

The crop is an important part of cooking in West Africa. *Digitaria exilis* is a grain traditionally used for porridges and steamed cooked food. The species is known to have high carbohydrate and protein levels.[17] These protein levels are seen with *Digitaria exilis* being rich in essential amino acids like methionine compared to other cereals like wheat, rice, and maize.[18] These qualities show that *Digitaria exilis* could be a good source of food and if the right characters are selected for it could turn into a useful crop.

Digitaria exilis has also good sustainability qualities and can survive in difficult environments. The crop maintained germination rates after being exposed to washing and scarifying treatments. Also *Digitaria exilis* germinated well in various soil types like sand and loam.[19] The crop requires little input with surviving just on rain. It is adapted to marginal land doing well in poor soil and being drought resistant.[20] All these characteristics make *Digitaria exilis* a possible good crop candidate.

Digitaria exilis can be harvested in many ways. Some farmers just uproot them to get the seeds, but other methods may be more effective. People use sickles to cut the region with seeds instead of destroying the whole plant. Another process is threshing which can vary by region. One way of threshing is beating the straw to extract the grain or it can be done by trampling the straw to extract the seeds. After the grains must be dried usually for a few days. The crop has very small seeds surrounded by tough kernels so they are ground into a fine powder to be incorporated in cooking.[21]

On the other hand, *Digitaria exilis* does have some implications with regard to its ability to be a crop candidate. One thing the crop struggles with is competing with weeds. So farmers are required to remove weeds after sowing. Another thing is that fields after planted with *Digitaria exilis* require time to regain nutrients in the soil. Usually a field must fallow for 1–2 years.[21] These are some qualities that need improvement and through artificial selection can be achieved.

Digitaria exilis is the oldest native cereal crop in West Africa at around 5 millennia BC. For that region, *Digitaria exilis* is vital for food security.[20] Farmers emphasize the crop's cooking ability, growth cycle, productivity, and size.[22] Regardless, the crop is facing difficulties with keeping diversity and production up because of lack of harvest and lack of technologies for processing.[21] With that in mind, it is important to maintain and develop the fonio for producers and consumers. *Digitaria exilis* has many potential future uses such as cooking or technological purposes so it is necessary to select for good kernel properties to develop it into a new food source as a crop for the world.[17]

Nutritional value of *Digitaria exilis*

Digitaria exilis holds high nutritional value to humans.[7] The nutritional value of decorticated fonio is about 1470 kJ and for whitened fonio 1430 kJ per 100 gram.[9] The nutritional value of its product is very high without suffering from taste.[23] Furthermore, it is a good source of fibres and phytonutrients.[23]

Digitaria exilis holds high nutritional value to humans.[7] It contains methionine and cysteine, two amino acids that are important to human survival.[7] These two amino acids, however, are lacking in wheat, rice, maize, and other cereal crops.[7] Moving from the amino acid level to the macromolecule level, *D. exilis*, compared to other cereal crops, has greater protein, carbohydrate, and fiber content.[24] *Digitaria exilis* has more protein and

fiber content than rice.[24] Additionally, *D. exilis* has more carbohydrate content than millet, sorghum, and maize.[24] Therefore, the nutritional benefit from *D. exilis* outweighs the nutritional benefits from other similar cereal crops.

Content of Carbohydrates, Lipids, Proteins and Minerals of *Digitaria exilis* compared to other cereals (% dry weight)

Nutritional value of *D. exilis* compared with other cereals				
	Carbohydrates	Lipids	Proteins	Minerals
Decorticated Fonio	84-86	3.3- 3.8	9- 11	1- 1.1
Whitened Fonio	89- 91	0.8- 1.0	7- 9	0.3- 0.6
Rice	86	2.5	10	1.4
Whitened Rice	90	0.9	8	0.5

Source:[9]

Mineral content

D. exilis shows generally mineral contents that are in the range of other cereals (Table 1). But it contains much more sulphur than other cereals and they are also mainly concentrated in the grain and not in the husk.[9] Methionine, which is built up with sulphur, is accumulated in fonio twice the amount compared to corn or millet and three times compared to rice.[9] Some of the minerals are mostly concentrated in the husk which are therefore lost while hulling.[9] The remaining fatty acids in the decorticated grain are mainly unsaturated fats like linoleic and oleic acid.[9] The most present saturated fat is palmitic acid.[9] It has been reported that Digitaria exilis is an optimal food for people having diabetic problems. .[25]

Mineral content of Digitaria exilis, decorticated and whitened

Macro and Microelements of *D. exilis*		
	Decorticared Fonio	Whitened Fonio
Macroelements (In % dry weight)		
Calcium (Ca)	0.022	0.01
Magnesium (Mg)	0.13	0.01
Phosphorus (P)	0.25	0.06
Potassium (K)	0.17	0.02
Sulphur (S)	0.16	0.16
Microelements (ppm)		
Copper (Cu)	6.8	3.0
Iron (Fe)	38.8	27.3
Mangan (Mn)	21.6	4.9
Sodium (Na)	72.3	58.5
Zinc (Zn)	33.4	21.8

Source:[9]

Effect of processing on nutritional values of *Digitaria exilis*

There are several factors that can alter this pre-existing high nutritional content. One method that distorts the nutritional composition of *D. exilis* is the extensive processing required to bring it to an edible state.[6] During milling, the outer layers of its grains are removed, and these layers are where the nutrients are primarily located.[6] Therefore, with the loss of the outer layers of the grains, there is a loss in the nutrient content.[6] As a result, the iron, zinc, and phytate concentrations present in the edible form of *D. exilis* are reduced in abundance relative to their respective concentrations before processing.[6]

Digitaria exilis and gluten

The coeliac disease is an intolerance to a certain prolamine, so called gluten in wheat, which can cause chronic small intestinal problems.[23] Fonio is closer to sorghum and rice than to wheat, and therefore it does not contain the sequence of amino acids that cause this intolerance.[9] Fonio is therefore an interesting crop for people suffering from coeliac disease.[23]

Effect of agricultural practice on nutritional values of *Digitaria exilis*

Additionally, the nutrient content and yield of *D. exilis* can be affected by the soil nutrition present in the varying climatic conditions of West Africa, which is where *D. exilis* primarily grows.[26] Through experimentation, it was seen that the nitrogen concentration in the soil has the greatest affect on the nutrition and productivity of *D. exilis*.[26] When nitrogen was added to the soil in limited quantities with an excess of potassium and phosphorus, productivity of *D. exilis* increased by 22%.[26] Such significant results were not observed, however, when either potassium or phosphorus was added to the soil with excess nitrogen and phosphorus, or with excess nitrogen and potassium, respectively.[26] On the contrary, when nitrogen, phosphorus, and potassium were added to the soil in equal and moderate quantities, the greatest amount of yield and nutrition was seen.[26] This overall trend is seen as a result of the low rainfall and poor soil conditions that *D. exilis* naturally grows in.[26]

Additionally, farmers evaluated *D. exilis* landraces on key agricultural characteristics.[27] These included ease of processing, productivity, grain size, and facility of harvesting among many others.[27] Based on the evaluations given by these farmers, it can be seen that the agronomic traits (traits that allow for a greater ease of growing to farmers) of *D. exilis* would be having a big and long stem, having a long panicle with lots of grains, and having a large grain size.[27] These traits allow for easier growing and harvesting by farmers.

From an evolutionary biology standpoint, information about the nutritional content of *D. exilis*, factors that modify its nutritional content, and its agronomically important traits can be of importance under artificial selection of *D. exilis*. The *Digitaria exilis* landraces that exhibit the greatest amount of nutrition and display the agriculturally important qualities can be further cultivated under improvement.[27] As a result, *Digitaria exilis* can serve as a perennial crop to provide the human species with food security in the future.

Volatile compounds

One of the things that makes *Digitaria exilis* such a sought after grain is its chemical composition. *Digitaria exilis* is an important source of nutrition because it is rich in methionine, which is an amino acid that is vital to human health. Since *Digitaria exilis* was such an important part of people's nutrition, researchers wanted to find out what made it taste so good. Volatile compounds were used to determine what contributed to the flavor of *Digitaria exilis*. It was found that *Digitaria exilis* contains several amino acids that readily react with monosaccharides to form alkylpyrazines. There were three types of volatiles: those formed from starch degradation, those formed from reactions between starch and proteins, and those formed through lipid oxidation.[28]

Physicochemical properties

One of the things that makes *Digitaria exilis* unique is its physicochemical properties. The physicochemical properties of *Digitaria exilis* can differ depending on if its starch is natural or succinylated. The pH of succinylated *Digitaria exilis* is lower than that of natural *Digitaria exilis*. This could be because some of the molecules introduced by succinylation resembled those of acetylation. While succinylation does decrease the pH of starch, it can increase some of its properties such as bulk density and water absorption capacity. The difference in bulk density is caused by the particle size decreasing as the bulk density increases. Succinylation increases the water absorption capacity of the starch which indicates that it could be helpful in some food products such as dough.[29]

Chemical composition

Compared to starches like *D. iburua* and *Eleusine coracana*, *Digitaria exilis* has more branched molecules. This was an important finding because although it has more branched molecules, it has fewer chains than the other starches which is unusual chemically. Aside from these differences, most other chemical characteristics were very similar to rice which was not surprising because *Digitaria exilis* and rice are both starches of the A. crystalline type.[30] Additionally, the microstructure of *Digitaria exilis* was studied, and it was discovered that it is very similar to the grain millets. Researchers found that *Digitaria exilis* is most abundant in protein bodies and that most of the protein is located towards the center of the cell. The specific structure of *Digitaria exilis* was analyzed and it was found that it is surrounded by thin bracts and two glumes. The caryopsis, a type of fruit that contains a pericarp that is fused with a thin seed coat, of the *Digitaria exilis* contains several layers that serve the purpose of protecting the endosperm and embryonic tissues.[31] The composition of fonio can differ depending on what part of the world you are in. The main differences are in the protein and fiber content. This information could be useful in giving people dietary advice if their diet is lacking a certain protein or fiber.[32]

See also

- *Digitaria compacta*, raishan, used as a grain crop in northeast India
- *Digitaria iburua*, black fonio, used as a crop in West Africa
- *Digitaria sanguinalis*, considered a weed around the world, but traditionally used as a grain crop in Europe

Notes

a. "also known at Findi, Fonio, Hungry rice, Fonio blanc and Petit mil is the dry seed of Digitaria exilis, a grass indigenous to West Africa"[2]

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