



Oasis wheats of the South of Algeria: landraces, cultural practices and utilization

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Abstract Wheat populations cultivated in the Saharan oases have been considered as potential parental germplasm for the improvement of drought, heat and salt tolerance. However, risks of genetic erosion have been reported, related to the degradation of the oases cropping systems and the introduction of modern wheat varieties. A better description and characterization of the Saharan wheat landraces is therefore required to make more effective their utilization in breeding. The present study was conducted among fourteen oases distributed in three locations of South Algeria (Adrar, Tamanrasset and Tindouf). In total, 187 samples of wheat landraces were collected from farmers' fields and a survey was carried out to better understand the agronomic practices applied to the crop. Three durum and 38 bread wheat landraces were

identified. Most of them appeared to be specific to locations or oases. Forms that differed on spike or grain characteristics were described, and botanical varieties were identified within most landraces. The survey revealed that farmers choose the landraces to be grown according to their ability to face the specific constraints affecting their cultivation in the different oases and the characteristics of their grain end-use. This observation is likely to explain the maintenance of traditional landraces in the oases, despite the different factors threatening these cropping systems. The importance of documenting and collecting the wheat landraces grown in the Saharan oases, evaluating them for their tolerance to abiotic factors and using them in improvement programs, is emphasized.

Keywords Oasis · Saharan wheat · Landraces · Farmer's practices · Utilization · Algeria

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Introduction

The presence of wheat in the Saharan oases had been reported by several travellers like Follie (1792) and Adams (1810), but the description of the different landraces, their agronomical characteristics and their cultivation only started during the twentieth century. Their morphological peculiarities, extreme earliness and high susceptibility to rusts have been noted by Ducellier (1909). A first classification of these landraces has been proposed by Ducellier (1920). Many authors previously reported the wide diversity of forms in Saharan wheat in Algeria, Libya and Morocco (Miège 1924; Ciferri and Garavini 1941; Erroux 1952, 1958; Perrino et al. 1976, 1984; Al Alazzeh et al. 1982; Hammer and Perrino 1985; Benlaghli et al. 1990; Guarino et al. 1991). Zaharieva et al. (2014, 2015) listed the main landraces mentioned by these authors and summarized the few diversity and evaluation studies. They also emphasized the potential interest of the Saharan genetic resources for wheat improvement. Indeed, Saharan wheats have been reported to be tolerant to drought (Ducellier 1920; Toutain 1977), heat (Ducellier 1920; Rodriguez 1932; De Arana 1934) and salinity (Erroux 1952; Toutain 1977) and to have a good breadmaking quality (Erroux 1962).

The diversity of Saharan oasis wheat is however endangered by the introduction of modern cultivars that have progressively replaced the traditional landraces (Zaharieva et al. 2014) and by the physical and socio-economic changes of oases that were deeply modifying their functioning (White 2007). Saharan agricultural systems are drastically threatened by the encroachment of sand dunes (Boulghobra et al. 2015), the rapid decline in groundwater resources and the salinization of soil and water due to poor management (Brooks et al. 2003), as well as by the degradation of the traditional irrigation systems (Remini and Achour 2008). They are also endangered by the development of non-agricultural activities and the migration to cities of the younger population which have led to the progressive abandon of the agriculture (Idder and Bouammar 2011). Given the various threats of disappearance of the Saharan wheat, it is therefore all the more important to have a better knowledge of the present diversity and cultivation of wheat in Saharan oases. The objectives of the present study, which focuses on oases of South Algeria (Adrar,

Tamanrasset and Tindouf locations), were to (1) list the different landraces still cultivated today, comparing them to those reported in previous studies, (2) describe the cultural practices applied to the crops and (3) make an inventory of the different uses of wheat in the traditional diet of the Saharan population.

Material and methods

General characteristics of the studied area

Three prospection missions and surveys were carried out in 2011 in the South of the Algerian Sahara, in the locations of Adrar, Tindouf and Tamanrasset, situated at 1400, 1700 and 1900 km of Algiers, respectively (Fig. 1). In opposition to the North of Algeria which is under the influence of the Mediterranean climate (type Csa of the Köppen–Geiger classification), the three locations are characterized by a warm desert climate (type BWh of the Köppen–Geiger classification) with a long and hot summer (maximal temperatures up to 50 °C) and a short and moderately warm winter. Differences of temperatures between day and night are very high. Windstorms and sandstorms are frequent whereas rainfall is rare (less than 50 mm per year) and soil and water are often saline.

The Adrar location includes the Touat and Gourara regions. The Touat is located to the South of the Grand Erg Occidental, to the East of the *erg* (sandy desert) Chech and to the South-East of the Tademait Plateau. It contains a string of small oases distributed along the eastern edge of the *wadi* (valley) Messaoud, a continuation of the *wadi* Saoura. Rainfall is very low and irrigation is required for cultivation. The soil is generally sandy-loamy. This region is well-known for its traditional irrigation system by *foggaras*, gently sloping underground channels transporting water from an aquifer or water well to surface for irrigation. The Gourara is located between the Grand Erg Occidental and the Tademait Plateau. Rainfall is low but strong showers can occur. Winds are frequent, particularly during spring. Soils are sandy-loamy and reddish-brown (Berkani 2012). The region is known for its *quasrias*, systems of comb-shaped pits that distribute water between different fields (Berkani 2012). The Tamanrasset location is located in the Hoggar Mountains. Temperatures in summer are slightly moderated by elevation and winters are mild. There is very little

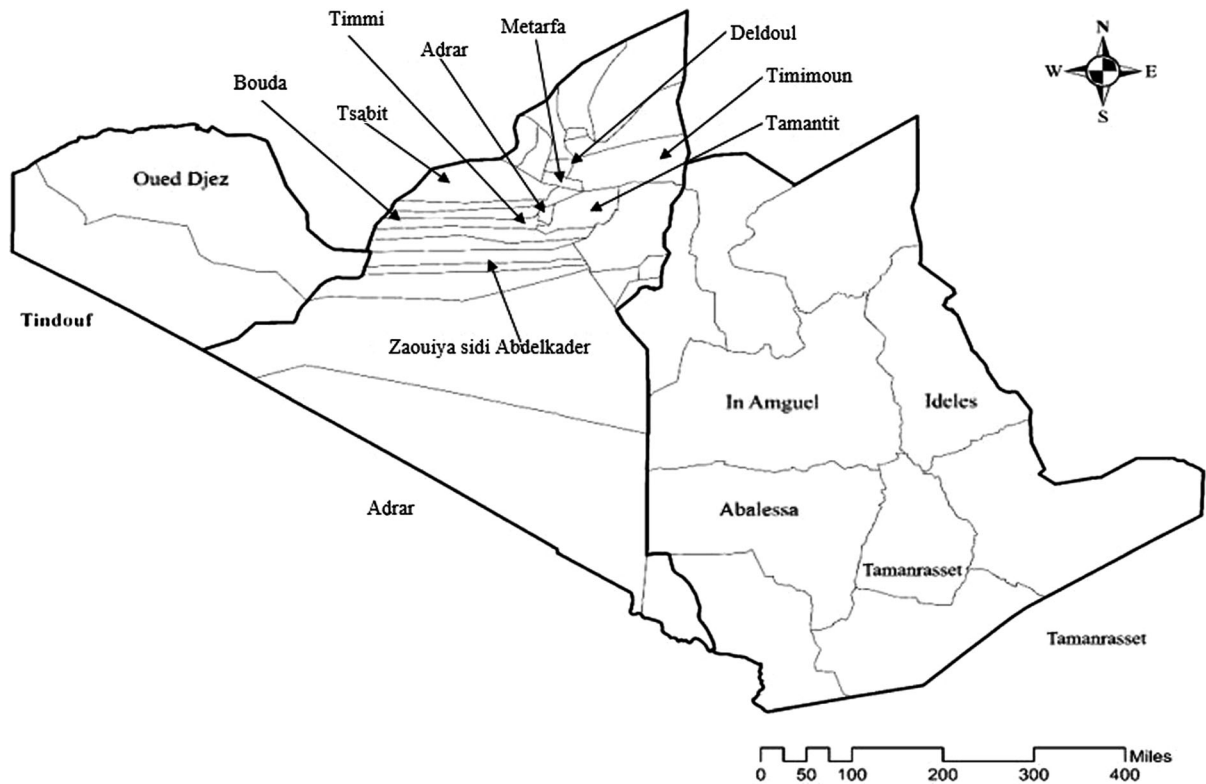


Fig. 1 Map of the study area

rain throughout the year. The Tindouf location is located at the border with Morocco, Mauritania and Western Sahara. It is characterized by extremely hot summers and very warm winters. There is very little rain for most of the year, generally concentrated in February and September–October. The region can be hit by rare events of heavy rain.

Collecting missions and surveys

The survey was carried out in May and coincided with the wheat harvest. A total of 187 samples were collected in 14 oases. In order to ensure a better representativeness of the prospection, wheat samples were collected in several oases of each location, in fields of farmers still cultivating landraces, using traditional cultural practices and producing traditional wheat products. In the Adrar location, 98 samples were collected in nine oases (Adrar, Timimoun, Bouda, Tsabit, Tamantit, Zaouia Sidi Abdel Kader, Daldoul, Timmi and Metarfa), at altitudes between

220 and 258 m. In the Tamanrasset location, 84 samples were collected in four oases (Abalessa, In Amguel, Ideles and Tamanrasset), at altitudes between 918 and 1478 m. In the Tindouf location, 5 samples were collected in one oasis (Oued Djez) at an altitude of 394 m. Each collected sample was composed by at least 100 spikes. For each sample, the name used by the farmer to identify the landrace was noted. Glume color, awn presence and length, spike density (normal or compact), spike type (normal or speltoid), glume pubescence (glabrous or pubescent), glume shape (normal or potbellied), kernel color (white or red), glume color (white or red) and awn color (same color as that of glumes or black), were noted for each sample, leading in most cases to distinguish several “forms” (Erroux 1962) within the landraces. Botanical varieties were identified according to the botanical classification of Saharan wheats proposed by Erroux (1962) and the Dorofeev et al. (1979) diagnostic-morphological classification with identification key to infraspecific taxa. Dorofeev et al. (1979) describes two

subspecies of *T. aestivum*, subsp. *aestivum* (European wheat) and subsp. *hadropyrum* Flaksb Tzvel. (Asiatic wheat). The Asian subspecies *hadropyrum* is subdivided into three groups of varieties: convar. *rigidum* A. Filat. et Dorof. (short and rough awns, developed rigid glumes with well-marked venation, keel tooth always straight, caryopses firmly enclosed by palea and lemma), convar. *semirigidum* A. Filat. et Dorof. (awned or awnless and semi-robust spikes, glumes less coarse than those of convar. *rigidum*, with less distinct venation, easy to thresh) and convar. *inflatum* A. Filat. et Dorof. (inflated glumes and bent awn-like appendages or short awns). Spikes of subsp. *aestivum* (European wheat) are usually long, dense to lax, awned or awnless, dorsally compressed.

The interviews carried out in the Adrar and Tamanrasset locations concerned farmers aged between 60 and 80 (26 farmers in the Adrar location and 27 in the Tamanrasset location, respectively). The questions of the survey concerned the cultivated landraces and their main characteristics (morphology, earliness, tolerance to abiotic stresses, resistance to pests and diseases), the cultural practices (sowing date, mode and frequency of irrigation, fertilization, date and stage of harvest, mode of conservation) and the wheat homemade products. We also asked them about the role played by women in wheat cultivation and transformation.

Results

Species, landraces, and forms within landraces present in the oases

In the Adrar location, out of the 98 samples collected, 85 were constituted by bread wheat (*Triticum aestivum* L.), seven by durum wheat (*Triticum durum* Desf.), five by a mixture of bread wheat landraces and one by a mixture of bread and durum wheat (Table S1). The durum wheat landraces cultivated in pure stand were identified by farmers as Bouchaatot, Mekkaoui and Tazi (this last name being also given by farmers to bread wheat samples). Two types of bread wheat mixtures were observed, the first one being between Hamra Touatia and Bel Mabrouk and the second between Bel Mabrouk and Oum M'Rakba. Durum wheat was also found in one case in this last mixture. In this location, 26 bread wheat and two durum wheat landraces were identified (Table 1). The bread wheat

Bel Mabrouk and the bread and durum wheats called Tazi were the most frequent, being identified in four oases. The landraces Hamra, Oum M'Rakba and Sebaga were present in three oases. We identified ten different landraces in Metarfa (all bread wheats), ten in Tsabit (nine bread wheat and the durum wheat Tazi) and nine in Timimoun (eight bread wheats and the durum wheats Tazi and Bouchaatot). Five landraces were found in the Timmi and Adrar oases. In Bouda and Zouiyet Sidi Abdelkader, only one landrace was identified. In the Tamanrasset location, out of the 84 samples collected, 80 were constituted by bread wheat and four by durum wheat landraces. A total of 18 landraces were identified. The cultivars Manga, Hamra and Guemh were the most frequent. Eight different landraces were found in Ideles and Tamanrasset, seven in Amguel and six in Abalessa. Among the durum wheat landraces only Mekkaoui was grown in this location. In Tindouf, only bread wheat was found. Four landraces were identified, namely Bahmoud, Guemh, Guemh Lahmar and Oum M'Rakba.

In total, 41 landraces were identified in the studied region (Table 1). Hamra was found in seven out of the 14 oases, while Guemh and Manga were present in five oases. Only one landrace (Guemh) was found in the three locations, while four of them (Hamra, Manga, Bent Embarek and Chouitar) were found in both the Adrar and Tamanrasset locations. While 20 landraces were present only in the Adrar location, 13 others were grown only in the Tamanrasset location. Three of the four landraces cultivated in Tindouf (Bahmoud, Oum M'Rakba and Guemh Lahmar) were also present in the Adrar location. According to the survey, seeds of these landraces were brought from Adrar. The fourth landrace, Guemh, was purchased on the local market in the Tindouf location. Nine landraces, namely Hamra, Guehm, Manga, Tazi (bread wheat), Tazi (durum wheat), Bel Mabrouk, Oum M'Rakba, Mekkaoui and Sebaga, were found in more than two oases. Seven other landraces were found in more than one oasis. The remaining 25 landraces were present in only one oasis.

Most cultivars collected bore an Arabic name except Aân Amelal, a name from Berber origin, which means “white flour”. In some cases, the name of the landrace referred to its origin: Mekkaouiya (brought from Mecca during the pilgrimage), Touatia (from the Touat region), Skandaria (name of a district in the Ksar of El Ouajda in the Gourara region), Hamra

Table 1 List and location of cultivation of the identified wheat landraces (Gray boxes indicate the presence of the landrace in the oasis)

Landrace	Adrar									Tamanrasset (Hoggar)				Tindouf	Number of oases where the landrace is present	Number of forms distinguished within each landrace
	Gourara			Touat						Ideles	Tamanrasset	Abaléssa	In Amguel	Oued djéz		
	Metarfa	Timimoun	Daldoul	Adrar	Bouda	Tamanit	Timmi	Tsabir	Zaouia Sidi							
Hamra															7	8
Guemh															5	8
Manga															5	8
Tazi (bread wheat)															4	6
Tazi (durum wheat)															4	4
Bel Mabrouk															4	11
Oum M'Rakba															4	6
Mekkaoui (durum wheat)															4	6
Sebaga															3	2
Bahmoud															3	4
Baida															2	2
Bent Embarek															2	4
Chouitar															2	3
El Farh															2	3
Mekkaouiya															2	2
Moumna															2	6
Aân Amelal															1	1
Adjilane															1	2
Baida Lakhfifa															1	1
Bent El Hamra															1	2
Bouchaatot (durum wheat)															1	1
Bourbaa															1	5
Ch'Guira															1	2
Chater															1	1
Farina															1	2
Guemh Lahmar															1	1
H'Bircha															1	1
Hamra Lakhfifa															1	1
Hamra Touatia															1	3
Hanafi															1	1
Houiya															1	1
Lahmira															1	2
Lakhfifa															1	1
Masraf															1	1
Oum Z'Hira															1	1
Ras El Mouch															1	1
Rati															1	2
Skandaria															1	2
Terouzi															1	1
Touatia															1	2
Zeghloul															1	1
Number of landraces	10	9	2	5	1	2	5	10	1	8	8	6	7	4		

Touati (“red from the Touat”). Other names have a religious connotation, as Moumna (the believer) or El Farh (religious fest). The name Tazi (also called “colonizer’s grain”) indicates that the landrace is foreign to the region, having been introduced either during the French colonization, given through humanitarian aid or bartered with nomads or people foreign to the region. The names Bel Mabrouk (Mabrouk’s son), Bent El Hamra (El Hamra’s daughter), Bent Embarek (Embarek’s daughter) and Bahmoud tell us about the person who introduced the cultivar into the region. Some names refer to morphological characteristics of the plant (Oum M’Rakba = several nodes). Many relate to the morphology of the ear (M’Rakba = compact) or its colour (Baida = white, Hamra, Lahmar, Lahmira = red) or the presence of awns (Bouchaatot = hairs, Ras El Mouch = cat’s head). Others inform about the phenology (Sebaga, Chater, Chouitar, Lakhfifa and Ajlane = early, Bourbaa = four months’ cycle), Chater (earlier than Chouitar). Some names as Baida Lakhfifa (early white) or Hamra Lakhfifa (early red) are associated with both phenological and morphological traits.

It was not possible to obtain precise information about the date of introduction of the landraces, except in the case of the Tindouf location. According to the farmers, wheat was widely cultivated in the past in the G’rara oasis (25 km away from Tindouf). Seeds originated from Morocco and the grain was used only to make bread. Cultivation was abandoned in 1986, once flour was available in shops, and wheat has been progressively replaced by barley, which has an important place in the diet of the local population to make bread, couscous and soup (*h’rira*). In the Adrar and Tamanrasset regions, Saharan wheat is cultivated and used for family self-consumption and for religious events (*ziara*).

Within most bread wheat landraces different forms were distinguished (Table 1), based on spike and grain characters (Table S1). The landraces presenting the highest number of forms were Bel Mabrouk (11), Manga (8), Hamra (8) and Guemh (8). A majority of bread wheat samples (62.3%) had short awns, while 35.4 % had awnless spikes. The majority of forms (53.7%) had compact spikes. A small proportion (17.1%) had speltoid spikes. Samples with potbellied glumes with a more or less preeminent keel represented 88.6% of the total number. 38.8% had red glumes and 64.7% red grains. A total of 23 botanical

varieties were distinguished, the most frequent being *subhostinflatum* Palm. (20.7%), *heraticum* (Vav. et Kob.) Mansf. (13.2%) and *subbarbarossinflatum* Palm. (10.3%).

Agronomical practices

In the Saharan oasis, three traditional productions modes can be distinguished. In the first case, the farmer is the owner of the field. In the second case he rents the field of the owner (*kharass*). The rental is not in monetary form, the person who rents a field gives the owner part (generally half) of the harvest of dates, wheat and barley, the three main crops. The owner and the farmer agree on a definite number of kg of seeds per year also locally known as *guelba* (one *guelba* = 16 kg of seeds) according to the area, the number of date palms and to the quantity of water. If the harvest is not sufficient to comply with this rule, the person who rents the field must compensate with barley or wheat brought from the market. The renter (*kharass*) has also the opportunity to take all the production of secondary crops such as forage and vegetables (tomato, pepper, lettuce, garlic, onion). In the third case, the worker (*khamass*) works on the field of the owner. In return of the agricultural work done, the owner gives him 1/5 of the harvest of dates, wheat and barley.

Wheat is grown in small fields (called garden) located under date palms and fruit trees in the Tamanrasset area and under date palms in the Adrar and Tamanrasset areas. The size of the gardens is generally comprised between 0.5 and 5 ha in Adrar and between 2 and 6 ha in Tamanrasset. The cultivation and maintenance of the crop is done manually by the farmers. Sowing is done in small plots, called *guemoun*, whose size and number depend upon the availability of water. Their size is generally 2 × 3 m, 2 × 4 m, or 2.5 × 4 m. When the availability of irrigation water is limited, the size of the *guemoun* was only 1 × 2 m and a maximum of 30 *guemouns* is cultivated. In Tamanrasset, the size of the *guemoun* also depends on the inclination of the parcel. The flatter the surface is, the larger the size of the *guemoun* is. The *guemouns* taken together constitute a *matrak*, a group of *matrak* being called *s’riha*. According to the survey, sowing is generally done on the fly. In the Timimoun area, sowing is however sometimes done in poquets to limit the impact of rodents. The most common sowing date in the surveyed areas was at the

beginning of October. Sowing occurred sometimes later in October, according to the distribution and water availability. In Adrar, the sowing date is delayed until January if temperatures remain high. In Tamanrasset, the Baida landrace is sown in December because of its susceptibility to low temperatures. In the Ideles and Tamanrasset oases, sowing is also delayed to avoid the effects of frost. No fertilizer was used in gardens, particularly because of the remoteness of the points of sale, its unavailability or high costs and the lack of knowledge of the farmers about its use. Organic manure is brought during ploughing.

In both locations, irrigation is carried out by submersion. In the Adrar location, irrigation water is provided by *foggaras*. The water from the *foggaras* is distributed to the different gardens through a system called *quastria* consisting of a receptacle and comb types at its end. Water is routed from the *quastria* to the gardens through canals called *seguia*. Water stored in basins is channelled through canals called *abadou*. The distribution of water in the gardens depends on its availability. The number of gardens is often affected by the poor condition of the *foggaras*. Water is brought in average once a week but can be up to two weeks. In the Tamanrasset location irrigation is done by pumping water from wells. Failures of water suppressors and non-availability of spare parts often limit the access to water.

The duration of the growth cycle of the wheat plant was around 6 months. It was reduced to five months when temperatures were high and even to three and half to four months in the case of the earliest cultivars. Weeding was done manually and pesticides were not used by the farmers. In the Adrar region, no diseases or pests have been identified by the farmers. Conversely, in the Tamanrasset region, the farmers reported the occurrence of pests and diseases. In the oases of Ideles and Tahifet, farmers noted spike sterility symptoms, probably due to frost. In the oasis of Ideles, they reported the presence on the plant of honeydew called *assala*, due to aphids.

The harvest is from the end of March for the earliest landraces to early May in the Adrar location and from mid-May to June in the Tamanrasset location. After harvest and waiting for threshing of the ears, clumps are made and stored on the field and then covered to prevent bird attacks. The threshing of ears is done manually, using different techniques depending on the

hardness of the husks. It is done by hand when the grains easily detached from the ear and with the base of the leaf of date-palms or with glass bottles when the envelopes are hard.

In the past, in the *ksours* of the Adrar region, wheat was stored in kinds of silos made of clay, sand and straw of wheat or barley (*matmouras*). This mode of conservation is still found in the oasis of Tsabit. In other oases, it is rather stored in metal or plastic drums whose interior is covered with lime (*djir*) to prevent pest attacks, or in burlap sacks (*halfa*). Some farmers have a house granary (*guella*) to store their grains. Grains can be conserved from one to two years. Ears can be conserved up to seven years.

All the members of the family participate in the agricultural work in the garden. Men are most often involved in ploughing, sowing, weeding and harvesting. Irrigation and weeding are provided by the owner of the garden. Children take part in the garden work after working hours and during the week-end. After finishing the housework, women work in the garden in the late afternoon. Their role is preponderant in the choice of cultivars, their mixing, the threshing of ears and the grinding of grains (coarse = semolina or fine = flour).

Seeds are multiplied by the farmers themselves. Each year, part of the harvest is kept for the next sowing, the best ears being used to produce seeds. Landraces are sometimes grown in mixture. Landraces susceptible to bird's attacks are frequently found in mixture with landraces that are resistant, in order to reduce grain loss. Hamra Touatia, for example, is always used in mixture with other landraces. Most landraces are however cultivated in pure stand.

Traditional use of cultivars

Wheat is ground to obtain either semolina or flour using a stone grinder. There are two types of mills, one for a coarse grind and another for a fine grind. The walls of the grinding wheel are smooth in the first one, rough in the second. The speed of rotation also plays a role on the particle size, fast speed resulting in bigger particles. Three major traditional wheat product were identified, bread (*khobz* or *kesra*), couscous and soup (*hrira*) (Table 2). The main differences between the types of bread concern its thickness, the ingredients used and the cooking modes. In the Adrar location, the main products prepared from semolina or flour

Table 2 The different uses of wheat in the oases of the South of Algeria

Bread (<i>khobz</i>)	<i>khobz el chehma</i>	Fat-based bread
	<i>khobz m'batane/ m'radef</i>	Two sheets of dough stuffed with vegetables (tomatoes, onion, date..)
	<i>takdir</i>	Pieces of soft dough cooked in a sauce
	<i>khobz eneur</i>	Prepared in a <i>eneur</i> (terracota jar)
	<i>khobz el guella</i>	Prepared in a <i>guella</i> (terracota perforated jar)
	<i>khobz teguella / kesra</i>	Cooked under the hot sand
	<i>khobz rogueg</i>	Fine dough sheet prepared in a <i>tadjine</i> (metal or terracota plate)
Couscous	<i>berkoukess, mardoud, or aich</i>	Coarse couscous
	<i>aich srayar</i>	Couscous made with spices and medicinal plants (fenugreek, nigella, anise)
Other uses	<i>tirwaou</i>	Grilled wheat grains
	<i>gorgoz</i>	Grain crushed and boiled
	<i>zembo</i>	Immature spikes, harvested at the pasty stage, lightly grilled on the ash under hot sand and then crushed
	<i>hrira</i> (Soup)	Soup made with <i>zembo</i>

included *khobz el guella*, *takdir*, *mradeef*, *khobz eneur*, *khobz rogueg*, *khobz el chehma* (fat-based bread), *khoubz m'batane*, *mardoud* or *berkoukess* or *aich* (coarse couscous). In the location of Tamanrasset, known for its *khobz teguella*, were also found *khobz erguig* or *khobz rogueg*, *mardoud* or *barkoukess* or *aich*, *tirwaou* (grilled wheat grains) and *gorgoz* (grain crushed and boiled). Finally, the tall stems of Saharan wheats allow farmers to use straw (in addition to turnip, millet, sorghum, and perennial alfalfa) to feed livestock. Each family has a small herd consisting mainly of goats, which gives them a significant amount of milk for their daily needs.

Some landraces like Baida, Baida Lakhfifa, Manga or Skandaria are particularly appreciated for their taste (Table 3). Some are more specifically appreciated for the consumption of *zembo* like Chater or Mekkaouiya, others for the fabrication of bread, like Farina and Oum M'Rakba. Some landraces are used for the fabrication of specific breads (eg, Hamra and Manga for the breads *khobz el rogueg* and *kesra teguella*, respectively, in Abalessa). In practice, the grains of several landraces are generally mixed after the harvest in proportions depending on the desired use to prepare a specific product, the mixtures and proportions differing from one region to another and sometimes from one oasis to another in the same region. Conversely, a given landrace can be used for several products. For example, part of the plot can be harvested for the production of *zembo* when grains

are still at the milk stage while the other part is harvested at complete maturity to meet the needs of flour or semolina of the family.

Agronomical traits of cultivars

According to farmers, the choice of cultivars to be sown in a specific oasis is highly determined by the specific constraints of the environment and culinary requirements of farmers and their families. The agronomical characteristics of landraces that permit to face the climatic constraints, as well as the grain particularities that are favourable for the fabrication of a specific end-product are well known by the farmers. The agronomical traits mainly considered by farmers in their choice are productivity, earliness (in relation to the avoidance of specific stresses), low water requirement, resistance to birds, and easiness to thresh and grind the grain. The most productive landraces according to the farmers were Bahmoud, Baida, Bel Mabrouk, Bent Embarek, Guemh, Hamra, Houiya, Manga, Mekkaoui, Moumna and Ras El Mouch. The landraces Bahmoud, Baida Lakhfifa, Bourbaa, Chater, Chouitar, Hamra, Houiya, Lakhfifa, Mekkaoui, Mekkaouiya, Oum M'Rakba, Ras El Mouch, Sebaga and Skandaria were considered by them as the most drought tolerant. The landraces showing resistance to hot winds and bird attacks were Bahmoud, Bel Mabrouk, Manga, Tazi, Terrouzi and Zeghloul.

Table 3 Main agronomical characteristics and uses of some landraces cultivated in the oases of the South of Algeria

Landrace	Main agronomical characteristics	Uses
Bahmoud	Productive, early maturing, hard to thresh, resistant to birds attacks (Timimoun)	Bread, couscous
Baida	Productive, late maturing, easy to thresh and grind (Tamanrasset)	Bread, couscous (Tamanrasset), Appreciated for its taste (Ideles)
Baida Lakhfifa	Early maturing (Abalessa), easy to thresh and grind	Good taste
Bel Mabrouk	Productive, good tillering, late maturing, high spike fertility, beautiful light yellow grain, resistant to wind, easy to grind (Adrar)	Bread, couscous and soup of <i>zembo</i> (Adrar)
Bent El Hamra	Late maturing, easy to thresh, quite difficult to grind	Bread, couscous
Bent Embarek	Productive, late maturing, high spike fertility, high thousand kernel weight, easy to thresh and grind ^a	Flour, bread, couscous, semolina (Adrar)
Bouchaatot	Hard to grind, susceptible to the wind	Appreciated for couscous (Timimoun)
Bourbaa	Early maturing, susceptible to shelling, easy to thresh and grind	Bread, couscous, <i>zembo</i>
Ch'Guira	Late maturing, easy to thresh and grind	Couscous, bread, flour, semolina (Tsabit, Adrar)
Chater	Very early maturing ^b , long spike, high spike fertility, low water requirements	<i>Zembo</i>
Chouitar	Very early maturing, low water requirements (Tamanrasset) ^c	<i>Zembo</i> (Adrar), bread, couscous (Tamanrasset)
Farina		Bread (Adrar)
Guemh	Productive, easy to thresh, (Tamanrasset)	Bread, couscous
Hamra	Productive (Tamanrasset), early maturing, easy to thresh and difficult to grind (Timimoun), easy to thresh and grind (Abalessa, Ideles)	<i>Zembo</i> , bread, couscous, flour, semolina (Timimoun) appreciated for bread (Abalessa, Tamanrasset), particularly for bread <i>khobz el rogueg</i> (Abalessa) appreciated for couscous and soup (Adrar)
Hamra Lahfifa	Late maturing, susceptible to frost	Bread, couscous (Abalessa, Tamanrasset)
Hanafi	Easy to thresh	Generally used in mixture with other landraces
Hbircha	Susceptible to shelling	Bread, couscous, soup
Houiya	Productive, early maturing	Bread, couscous
Lakhfifa	Early maturing, easy to grind	Couscous, bread, flour, semolina (Tsabit/Adrar)
Lahmira	Easy to thresh	Couscous, bread
Manga	Productive, late maturing, resistant to lodging despite of its high stature, hard to thresh and grind, resistant to wind and birds attacks	Bread <i>kesra teguella</i> (Abalessa), appreciated for its good taste (Tamanrasset)
Mekkaoui	Productive, late maturing, hard to grind	Bread (Tamanrasset)
Mekkaouiya	Early maturing, easy to thresh and grind, susceptible to birds attacks (Timimoun)	<i>Zembo</i>
Moumna	Productive, late maturing, easy to thresh (Tamantit)	Couscous, bread
Oum M'Rakba	Early maturing, drought tolerant	Flour, bread, couscous (Adrar)
Ras El Mouch	Productive, very early maturing	Bread, couscous
Sebaga	Very early maturing, low water requirements, easy to thresh and grind, susceptible to the wind (Timimoun)	Flour, semolina (Timimoun) appreciated for the couscous
Skandaria	Productive, early maturing (Tamanrasset), susceptible to shelling, easy to thresh and grind	Appreciated for its taste (Tamanrasset)

Table 3 continued

Landrace	Main agronomical characteristics	Uses
Tazi	Resistant to the wind and birds attacks ^d	Flour, semolina (Timimoun)
Terrouzi	High stature ^e , hard glumes and grain, resistant to birds attacks	Bread, couscous
Zeghloul	Resistant to birds attacks ^d	Flour, semolina (Timimoun)

^aSometimes called Farina for this reason

^bIn the past, cultivated during periods of famine to obtain grain early in the season, today it is sometimes neglected by farmers because they consider that it can bring the “evil eye”

^cIn Tamantit and Ouled el Haj el Mamoun, tends to be substituted by Bel Mabrouk because farmers consider that it is less productive in recent years

^dMainly due to ist awned spikes

^eAlso called *cheriré* (tall and thin man)

Discussion

Most wheat landraces identified in this study were bread wheats. Two landraces, Bouchaatot and Mekkaoui, were identified by the farmers as durum wheat. Some samples referred by the farmers as Tazi were also durum wheats. Finally durum wheat was found to be cultivated in a mixture of bread wheat. This limited presence of durum wheat in the Adrar, Tamanrasset and Tindouf locations is in good accordance with observations done by Chevalier (1932) and Erroux (1962) about the scarcity of durum wheat in Saharan oases. The presence of durum wheat in Sahara has been previously reported only in the Hoggar by Ducellier (1929) who described a durum wheat landrace characterized by short and rounded glumes and by Erroux (1962) and Guarino et al. (1991) who reported the presence of the population Amekkaoui (probably similar to the landrace Mekkaoui we found in the Tamanrasset location). According to Chevalier (1932), the durum wheat landraces grown in the Saharan oases are originating from the neighbour regions and would have been introduced later than bread wheat. However, some forms have compact spikes like those cultivated in Oman (Al Khanjari 2005), suggesting crosses with durum wheats introduced from this region.

The present study confirmed the high variety of bread wheat landraces cultivated in the Saharan oases of South Algeria, and their morphological peculiarities making them different from the landraces cultivated in North-Africa under Mediterranean climate, as mentioned by Zaharieva et al. (2014). For most of the farmers, the introduction of new cultivars did not meet

the culinary requirements, these not having same taste and required properties for making bread or other derivatives.

A high diversity was observed among the bread wheat landraces for morphological traits and agronomical characteristics (Table 3). Most of the collected bread wheats belonged to the *inflatum* type (Ducellier 1920) characterized by short and potbellied glumes, frequently encountered in Turkestan, Iran and Afghanistan (Vavilov, 1987). This observation tends to confirm the hypothesis of a relationship between the Saharan and Asiatic bread wheats (Erroux 1962). They included awned and awnless forms referred by Ducellier (1920) as *aristatum* and *muticum*, respectively, and intermediate (short-awned) forms characterized as *breviaristatum* by Erroux (1962). It was also possible to distinguish from the spike characteristics, compactoid and speltoid forms, as well as some forms with attenuated Saharan characters, as described by Erroux (1962). Among the landraces present in the oases of Adrar and Tamarrasset, most were very early as noted by Ducellier (1909) and had high spike fertility (Erroux 1962). This high diversity and peculiarity of Saharan oases landraces are likely to be due to the diversity of origins of this germplasm (Zaharieva et al. 2014), the highly specific climatic conditions limiting the adaptation of landraces from other regions (Benlaghli et al. 1990) and the isolation of Saharan oases from the rest of the country.

Some of the landraces which presence was noted in this study had been previously reported in the same regions of Touat, Gourara and Tamanrasset. Hamra was observed in the Touat by Ducellier (1930) and Erroux (1962) and Ali Ben Maklouf in the Gourara

and Touat (Erroux 1962). More recently, Berkani (2012) reported the presence of Bel Mabrouk, Ali Ben Maklouf, Oum M'Rakba and Moumna in both Touat and Gourara, and of Hamra, Sebaga and Chouitar in the Touat region. Some landraces encountered in the frame of the present study oasis were also found in the oases of other regions. Hamra and Bent Embarek were reported in the Tidikelt (Erroux 1962). The presence of Manga has been noted in the oases of Tit, In Salah and El Golea (Erroux 1991) and in Libya where it is known under the name of Hoggari (Erroux 1962). Ben Mabrouk has been reported in Beni-Abbes and in the Tidikelt (Erroux 1991). These observations should be however considered with caution. As already emphasized by Erroux (1962) and Zaharieva et al. (2014), the nomenclature of landraces is frequently imprecise. The name is given by a farmer to the most representative form. The same name can correspond to landraces with quite different morphological and botanical characteristics (Table S1). For example, the term Tazi was found in this study to include both durum and bread wheats. Ch'guira, the name of a bread wheat landrace in the Timmi oasis (Adrar) and in the Hoggar (Ducellier 1929), refers to durum wheat in the Tafilalt in Morocco (Benlaghli et al. 1990). Reciprocally, a same landrace can have several names according to the oasis or the village where it is cultivated, making difficult an accurate comparison of germplasm grown in different locations. Finally, the same name can refer to different forms, with different morphological characters and consequently can belong to different botanical varieties (Table S1). For example, in the present work, the landrace Hamra was found to contain forms belonging to the varieties *transcaspicum* (Vav.) Mansf., *subturcinflatum* Udacz., *rufinflatum* (Flaksb.) Mansf., *subferrugineum* (Vav.) Mansf., *turcomanicum* (Vav. et Kob.) Mansf., *sub-barbarossinflatum* Palm. and *submeridionalinflatum* Palm. Diverse varietal types accumulated successively over time in the oases where spontaneous crossing and natural selection were promoted, leading to intermediate forms or to new forms with new characters, all difficult to associate with the referential types already known (Ducellier 1929). The prospector must be able to distinguish the form which, being the most abundant in the mixture, is identified by farmers and gives the name (Erroux 1958).

The high variety of landraces present in the South of Algeria and the diversity of their agronomical

characteristics allow the farmers to select the landraces according to the climatic conditions of the specific oases and the quality of their grain to elaborate specific end-products (Table 3). Our study revealed that farmers remain very attached to their local landraces which are specific to some locations or even oases. Transmitted within the family from one generation to the next one, the landraces constitute an ancestral family genetic heritage. The maintenance of this germplasm appeared closely linked to the characteristics of the environment, the culinary requirements of the farmers and their families, as well as the easiness to thresh the spikes and grind the grain, highly appreciated in landraces like Baida, Baida Lakhfifa, Bent Embarek, Ch'Guira, Mekkaouiya, Sebaga and Skandaria.

The main yield limiting factors in the oases are frost at flowering, water shortage and high temperatures during grain filling and hot winds at maturity. The lower temperatures in Tamanrasset, compared to Adrar, not only determined delayed sowing date but also the frequent choice of landraces with later flowering, like Manga, Baida and Bent El Hamra. In the oasis of Tamantit (Adrar), where there is a lot of wind, the cultivar Bel Mabrouk is highly appreciated because of its resistance to shelling. Conversely, Bourbaa, despite of its value to prepare *zembo* is being abandoned because its grains fall on the ground. The appreciation of farmers allowed identifying several landraces with potential tolerance to drought. Until now only the landraces El Klouf (Rodriguez 1932; De Arana 1934) and Fertass (Toutain 1977) had been clearly identified as drought tolerant. Several landraces (eg., Bahmoud, Manga, Tazi, Terrouzi and Zeghloul) have also been reported by farmers as resistant to hot winds and bird's attacks.

Some of our observations about the agronomical characteristics of the landraces and preferences of farmers confirmed previous information. The appreciation of Bahmoud (= Ali Ben Maklouf) due to its productivity, resistance to birds and taste, highly appreciated in the fabrication of couscous and bread, had already been mentioned by Foley (in Erroux 1962). The high productivity of Hamra, its easiness to thresh and grind, its utilization for the fabrication of a wide range of products and the good taste of its grain had been yet pointed out by Erroux (1962). The productivity of Manga, its resistance to lodging despite of its high stature, its resistance to the wind

and bird's attacks, but also the difficulty to thresh its spikes and grind its grain have also been reported by Erroux (1962).

Conclusion

The present study revealed that a broad diversity of wheat landraces, forms and botanical varieties is still present in the oases of South Algeria. Most landraces appeared very specific to a given location or oasis, but some were more widely cultivated. The presence of the last ones has been frequently reported in other Saharan regions. The nomenclature of landraces is however frequently imprecise. These names were attributed by farmers, generally in relation to a striking feature that can be present in landraces differing for many other traits. It is therefore difficult to draw precise conclusions about the genetic diversity just referring to the presence of landraces. It is consequently urgent to initiate molecular diversity studies on this material, in order to acquire a better knowledge of its allelic diversity and its evolution over time. The maintenance of the traditional landraces in the Saharan oases is strongly related to the importance for farmers to have at one's disposal a genetic material well adapted to the specific constraints of this peculiar environment and bringing the grain quality requested for the fabrication of their traditional plates. Many factors are however threatening the agricultural systems of the oases and genetic erosion cannot be excluded over the next decades. It is important to improve our knowledge of this germplasm that could constitute a valuable source of both diversity and tolerance to abiotic stresses in wheat breeding programs.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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