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in

Porceddu E. (ed.), Damania A.B. (ed.), Qualset C.O. (ed.).
Proceedings of the International Symposium on Genetics and breeding of durum wheat

Bari : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 110

2014
pages 131-138

The strategies to serve and conserve Moroccan durum wheat genetic diversity before it is lost

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Abstract. Morocco is considered as a center of diversity of many species, including *Triticum* spp. This diversity is under the verge of extinction and hence urgent actions are needed to conserve it. Many actions are undertaken to reach that goal. Collecting missions were undertaken across Morocco and accessions are preserved at Gene Bank of Morocco. To widen this collection, recently two collecting missions were undertaken. One covered the Atlas Mountains, Ziz and Daraa valleys and carried out during 2009-10 cropping season, and the other covered the northern part of Morocco and carried out during 2010-11. The number of accessions collected were 16 in the South and 6 in the North. To assess the variation present in the Moroccan material, accessions from different provinces were tested along with improved cultivars were tested at different experimental station during 2009-11. The results indicated that the most prevalent diseases were yellow rust and to some extent leaf rust. Some of the old accessions are good sources of resistance to these diseases.
To promote on-farm conservation of landraces, on-farm field experiments using the same sub-core collection were carried out at different places. The result of these trials revealed that almost all improved cultivars were selected both by farmers and scientists along with some landraces. The magnitude of the positive correlation between agronomic scores attributed by farmers and scientists shed light on the importance to involve farmers in selection. The main traits of selection by the latter are grain yield, biomass, grain size and color, and earliness.

Keywords. Morocco – Durum wheat landraces – Genetic diversity – Participatory plant breeding Rusts.

Les stratégies pour soutenir et conserver la diversité génétique du blé dur marocain avant qu'elle ne soit perdue

Résumé. *Le Maroc est considéré comme un centre de diversité de nombreuses espèces, y compris Triticum spp. Cette diversité est menacée d'extinction et des mesures urgentes sont donc nécessaires pour la préserver. Plusieurs actions ont été entreprises pour atteindre cet objectif. Des missions de collecte ont été menées à travers le Maroc et les accessions sont conservées auprès de la Banque de Gènes du Maroc. Pour élargir cette collection, deux missions de collecte ont été effectuées dernièrement. La première, couvrant les montagnes de l'Atlas et les vallées du Ziz et Daraa, a été réalisée durant la saison de culture 2009-10 et l'autre, dans la partie nord du Maroc, a été effectuée en 2010-11. Le nombre d'accessions collectées étaient de 16 dans le Sud et 6 dans le Nord. Pour évaluer la variabilité du matériel marocain, les accessions provenant de différentes provinces ont été testées et comparées avec des cultivars améliorés, dans différentes stations expérimentales en 2009-11. Les résultats ont indiqué que les maladies prédominantes sont la rouille jaune et, dans une certaine mesure, la rouille des feuilles. Certaines des anciennes accessions constituent des sources utiles de résistance à ces maladies.*

Pour promouvoir la conservation à la ferme des variétés locales, des expériences au champ, avec la même sous-collection, ont été réalisées dans différents endroits. Le résultat de ces essais a révélé que presque tous les cultivars améliorés ont été sélectionnés à la fois par des agriculteurs et des chercheurs à l'instar de quelques variétés locales. L'ampleur de la corrélation positive entre les scores agronomiques attribués par les agriculteurs et les chercheurs a mis en évidence qu'il est important d'impliquer les agriculteurs dans la

sélection. Les principaux caractères retenus par ces derniers pour la sélection sont le rendement en grain, la biomasse, la taille et la couleur du grain et la précocité.

Mots-clés. *Maroc – Variétés locales de blé dur – Diversité génétique – Sélection végétale participative – Rouilles.*

I – Introduction

The flora of Morocco consists of more than 7000 plant species with more than 20% of endemism. Owing to its richness, in terms of the number of species and the high rate of endemism, Morocco harbors two internationally recognized biodiversity hotspots, the Atlas mountains and the Rif mountains among the 10 Mediterranean Basin Biodiversity hot spots. Morocco is also considered as a center of diversity of many cultivated species including *Triticum* spp. The local landraces of these crops offer an important gene pool as sources of adaptation and tolerance to many biotic and abiotic stresses. This important genetic material is continuously subjected to genetic erosion due to habitat degradation and the adoption of the improved varieties that are reducing significantly the acreage grown to landraces in many parts of Morocco. This loss of diversity is detrimental as farmers, mainly in marginal areas, rely on this diversity for their income and well-being. These landraces harbor large amounts of genetic variability and they need to be conserved before they are lost.

Two main strategies were adopted to alleviate the genetic erosion: Preservation through *ex-situ* conservation and encouraging their on-farm conservation (*in-situ*) through local use. On-farm conservation through local use is undoubtedly the best and long-lasting strategy to serve and conserve the biodiversity. To reach this goal and to promote the local use of landraces, on-farm field experiments using a core collection were carried out at Errachidia (2009-10), Rich and Taounat (2010-11) and using farmer's participatory breeding/variety selection approaches to involve farmers in the process of selection in order to pave the way for a successful re-adoption and local use of landraces. Moreover, two collecting missions were undertaken during two consecutive years to explore areas that have not been covered or less covered in the previous missions and to broaden the genetic base. A total of 549 accessions of durum wheat were collected during previous missions and are preserved at INRA-Genebank. Their repartition by province is listed in Table 1. The geographic localization of some of these accessions is exhibited in Figure 1.

Collecting missions should be an on-going process in order to broaden the genetic base and to long-term conserve the diversity. However, the collected landraces are to be used in breeding programs as donors of valuable traits and/or promoted for their re-adoption by farmers. In order to screen good sources of resistance to biotic stresses and to select the best performing accessions amongst the old wheat previously collected and preserved in gene-bank, core collections covering all provinces were sown at Annoceur experimental station during 2009-2010, and sub-core collections, tested on-farm, were sown at Meknès (Morocco) and Njoro (Kenya) experimental stations during 2010-2011 cropping season.

Table 1. Number of durum wheat accessions available at INRA Settat Genebank and those tested at Annoceur during 2009-10and at Meknès (Morocco) and Njoro (Kenya) during 2010-11.

	Available	Tested at	
	At Settat	Annoceur	Meknès and Njoro
Province	Genebank	(2010)	(2011)
AGADIR	25	7	3
Al HOCEIMA	21	6	4
AZILAL	18	17	8
BENI MELLAL	29	9	2
BOUARFA	6	2	1
EL JADIDA	8	2	2
ERRACHIDIA	29	13	2
FES	44	11	5
KHENIFRA	22	5	1
KHOURIBGA	3	1	0
MARRAKECH	57	15	7
MEKNES	26	8	2
MISSOUR	2	0	0
OUJDA	51	14	4
OURZAZAT	27	19	10
RABAT	49	7	3
TANGER	3	1	0
TAZA	50	12	4
TETOUAN	52	16	3
TIZNIT	27	8	1
Total	**549**	**173**	**62**

Figure 1. Sites of some previously collected Durum accessions available at INRA-Settat Genebank.

II – Methodology

1. Collecting missions

Defining target areas to be covered by the survey and landraces collections a very important issue to avoid redundancy and to fill the gap. That is, to conduct surveys in areas that were not covered previously. For that purpose, information regarding the covered areas (number of collected accessions of durum wheat by province) during previous collecting missions was documented. The available accessions are listed in the Table 1, from where we might detect the gap to be filled. In addition to areas that were not covered, those where the number of accessions is less than 20 (Table 1) were re-prospected to have a larger collection.

The best period to do the survey and collection is at maturity growth stage to collect individual spikes to be increased by single-spike descent and separately evaluated. Moreover, to gather as much information as possible, a questionnaire was prepared beforehand. For each collected sample, the data recorded were: name of the site and its coordinates (geo-referenced data), label of the collection, local name of the collected wheat, kind of collection (grains or spikes), origin of the seeds (on farm production, bought from neighbors or local market), seed treatment before sowing, since when this wheat is cultivated, the reasons behind the use of these old wheats (yield, biomass, grain color and size, biotic and/or abiotic resistance/tolerance, quality criteria (bread, couscous, or other uses).

Since landraces are becoming scarcer and scarcer and to collect as much as possible, we adopted many strategies during the missions of collection. Landraces were then collected from:

i. Farmers houses (grain of previous year);

ii. Spikes from fields of landraces (mainly durum);

iii. Spikes of old cultivars from fields of improved cultivars;

iv. Spikes from threshing areas;

v. Grains from local markets.

The itineraries of the collecting missions of wheat landraces undertaken during 2010 (south) and 2011 (north) are shown in Figure 2. The first mission covered the Atlas mountains and ZIZ and DARAA valleys, including the area between Errachidia, Rissani and Marzouga (not shown on the map), and the second one covered three provinces (Chefchaouen, Tetouan, and Taounate) with 6 rural counties (Zinat, BniLeit, Al Hamra, Derdara, Bab Taza, and Kissane).

Figure 2. Itinerary of the collecting mission of wheat landraces undertaken during May-June 2010 (left) and during July 2011 (right), within the frame of ITPGRFA (FAO) – INRA Morocco project.

2. On-farm field experiments and Farmers' participatory selection approach

The on-farm trials were carried out at Errachidia during 2009-2010 and at Rich and Taounat during 2010-11 cropping seasons. A core collection of 62 accessions was chosen on the basis of the amount of seeds available in the genebank and area of collection (Table 1) along with 18 commercial cultivars as local checks (Table 2). The repeated local checks were assigned according to an augmented design to control the experimental error. Each experimental plot was 3 rows of 1.5 m each and 30 cm apart. Plots were 60 cm apart from each other within blocks and 1 m from each block. The experiments were carried out by farmers using their cultivation methods.

Table 2. Durum wheat improved cultivars included in the experiment carried out at INRA-Annoceur Experimental station during 2009-2010 and at Meknes and Njoro during 2010-2011

Durum wheat cultivars			
Amjad	**Marjana**	Ourgh	Anouar*
Amria	Marouane	Tomouh	Tarek
Irden	Marzak	***Vitron*** **	Jawhar
Isly	Nassira	Yasmine	Sarif
Karim	Oum Rabia	Massa*	

** Tested only in Meknès and Njoro.*
*** Not tested in Meknès and Njoro,*

At physiological maturity, two simultaneous approaches were adopted: screening by scientists just before the arrival of farmers; and screening by farmers in groups of 3 to 5 farmers. Both scientists and farmers were requested to give an agronomic score ranging from 1 (the worst) to 5 (the best entry) and the reasons of selecting or discarding a given cultivar.

3. Ex-situ field experiment

To evaluate the accessions previously collected and taking into account the amount of seeds available, 173 accessions and covering all provinces (Table 1) were evaluated at Annoceur during 2009-2010 and 62 of them were tested at Meknès and Njoro during 2010-2011, in addition to 18 commercial cultivars (Table 2). Experimental plots were two rows of 1 m long each and 30 cm apart and 60 cm between plots.

The main objective of this experiment was to evaluate these accessions regarding their reaction to the prevalent biotic stresses namely yellow and leaf rusts in Morocco (Annoceur and Meknès) and stem rust in Kenya (Njoro). The severity and response ratings for the adult plant reaction under field conditions to rust diseases were based on the modified Cobb scale, where the severity was scored from 0 to 100% and the host infection response was rated as I = immune response, no sign of infection; R = resistant, very small uredinia with necrosis; MR = moderately resistant, small to moderate uredinia with necrosis; MS = moderately susceptible, small to moderate uredinia with chlorosis; and S = susceptible, large uredinia without necrosis or chlorosis.

The experiment at Njoro was carried out during the main-season (sowing date: June 29, 2011) andit was possible because of the cooperation with CIMMYT, ICARDA and KARI-Njoro, under the auspice of BGRI.

III – Results and discussion

1. Collecting missions

Despite the wide area covered during the collecting missions and the strategy adopted, the number of collected landraces is no more than 16. The magnitude of genetic erosion is even worse

in the north since the collected accessions were only 6. This fact means that genetic diversity of Moroccan wheat is on the verge of extinction. So, collecting should be an ongoing process to conserves this diversity *ex-situ*.

2. On-farm field experiments and farmers' participatory selection approach

To adopt a long-lasting strategy of preservation of local landraces of a given crop, the involvement of farmers in selection of the best ones and promoting the local use of these selected materials is a prerequisite. However, to be realistic, the local landraces will not be preserved unless they perform at least as well as the improved cultivars. Otherwise, there is no way to convince farmers to do so. This is the reason behind the incorporation of the improved cultivars in the experiment.

The analysis of the scoring notes attributed by farmers and scientists revealed that these scores are highly correlated (Figure 3) meaning that the involvement of farmers in breeding programs is reliable.

These on-farm trials revealed that all improved durum cultivars incorporated in the experiments were selected. However, the breakthrough and optimistic achievement of this experiment is that amongst the 62 durum landraces screened, 17, 16 and 27 were selected by farmers at Errachidia, Rich and Taounat respectively. That is, the improved cultivars might be considered as the main threat of diversity but also that there is a hope to serve and conserve it through the promotion of the old accessions that exhibited the same or even better agronomic performances and hence reducing the magnitude of the genetic erosion.

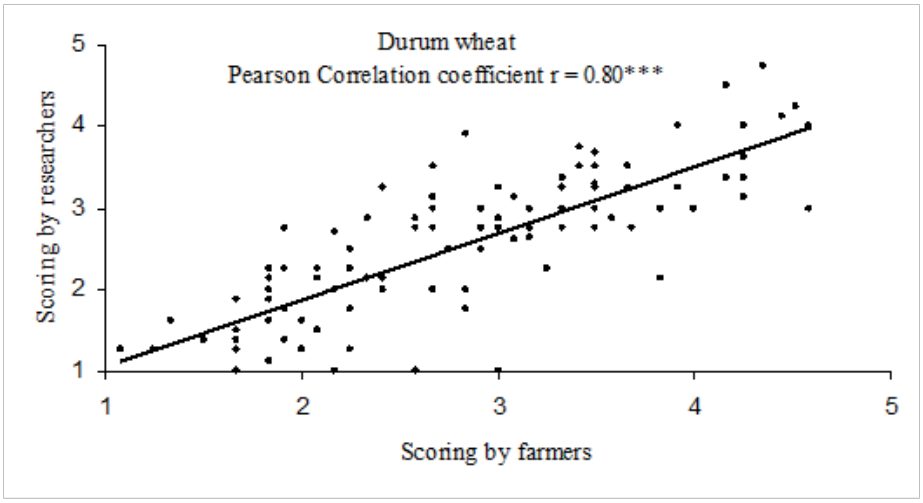

Figure 3. Magnitude of the correlation between scoring of wheat landraces and commercial cultivars by farmers and scientists.

3. *Ex-situ* field experiments

At Annoceur experimental station during 2009-2010, the severity of yellow rust on old durum ranged from 0 to 40% with 12% of them exhibited complete immunity. Leaf rust scores ranged from 0 to 15% with 44% of them were completely immune. The accessions that were relatively late compared to those at grain-fill stage exhibited a wide range of reactions towards yellow and leaf rusts, the most prevalent diseases. So even if these accessions were relatively late and consequently are subjected to the threat of extinction because they will be undoubtedly discarded

by farmers at least under the same conditions of Annoceur, some of them are good sources of resistance to yellow rust and/or leaf rust. The sound strategy to preserve them is through *ex-situ* conservation for future use in breeding programs. Regarding commercial cultivars, all of them had a high agronomic score and had a very good level of resistance against yellow rust where the most susceptible one had a severity of 5%, and a good level of resistance to leaf rust where the most susceptible one (Oum Rabia) had a severity of 20%.The agronomic score of old accessions ranged from 1 to 5 with some of the best performing one exhibited also a good level of resistance to both rusts.

A sub-subset of 62 landraces and 18 cultivars previously tested on-farm at Errachidia, Rich and Taounat were tested at Meknès and Njoro during 2010-2011. The result revealed that 22 accessions exhibited a very good level of resistance to stem rust where the relatively most susceptible one exhibited a severity of 20MS. Amongst them, 4 accessions were almost immune to stem rust (5R) but two of them (MGB 3060 and MGB 3065) were highly susceptible to yellow rust and the two others (MGB 3206 and MGB 3207) exhibited a very good level of resistance to yellow rust too (40R). These two latter accessions were not good from the agronomic performance point of view but are very promising lines as donors of resistance to both diseases (Table 3).

The severity of stem rust on improved durum cultivars ranged from 20MR to 70S, that is, none of them were immune to this disease and only four of them were relatively more resistant (20MR for ISLY and 20 MR-MR for AMJAD, NASSIRA and YASMINE). In contrast, yellow rust was not a real threat since the most susceptible one exhibited a severity of 30S (Table 4).So, using the best old landraces as donors of resistance to stem rust might further improve resistance to this threatening disease.

Table 3. List of durum wheat landraces resistant to stem rust at Njoro and their reaction towards yellow rust and their agronomic scores at Meknès during 2010-2011 cropping season.

MGB code (durum wheat)	Stem Rust (Njoro)	Yellow Rust (Njoro)	Yellow Rust (Meknès)	Agro Score (Meknès)
3207	5R	5R	40R	2
3206	5R	20S	40R	3
3060	5R	60S	80S	4
3065	5R	60S	80S	2
3054	10R	30S	60S	3
3055	10R	30S	80S	2
9393	15MR-MS	20RMR-90S	5 MR-MS	5
3085	15MR-MS	50SMS	60S	2
3082	15MR-MS	50SMS	80S	1
9399	15MR	10RMR	10MR-MS	5
3062	15MR	40S	80S	3
3108	15MR	50MS	80S	3
3059	15MR	60S	80S	3
3058	20MR	40S	80S	3
2812	20MR	60S	70S	2
3124	20MR	70SMS	70S	4
2997	20MR-MS	30S	50S	4
9404	20MR-MS	5RMR	10MR-MS	5
9302	20MR-MS	5S	0	5
3114	20MR-MS	20MS	60S	4
3071	20MR-MS	60S	70S	3
3064	20MS	60S	60S	2

Table 4. Reaction of improved durum wheat cultivars towards stem and yellow rusts at Njoro and towards Yellow rust and their agronomic scores at Meknès, during 2010-2011 cropping season.

Cultivars	Stem Rust (Njoro)	Yellow Rust (Njoro)	Yellow Rust (Meknès)	Agro Score (Meknès)
Isly	20MR	20S	Traces	4
Amjad	20MR-MS	5S	0	4
Nassira	20MR-MS	Traces	0	5
Yasmine	20MR-MS	30S	0	4
Sarif	30MR-MS	0	0	5+
Marzak	40MR-MS	Traces	Traces	4
Oum Rabia	40MR-MS	5S	0	4
Tomouh	40MR-MS	TR	5S-MS	3
Jawhar	40MR	0	Traces	4
Ourgh	40MS	5S	0	3
Amria	50S	20S	10 MR-MS	5
Massa	50S	0	0	5+
Anouar	60S	Traces	20R-MR	5+
Irden	60S	5S	40MR-MS	5+
Karim	60S	Traces	5MR	5
Tarek	60S	0	0	5
Marouane	70S	40MR-MS	40MR-MS	4

IV – Conclusion

Genetic diversity of Moroccan wheat is undoubtedly on the verge of extinction, bearing in mind that despite the wide areas covered during the collecting missions and the strategy adopted, the landraces were very scarce mainly in the northern part of Morocco.

The main reasons behind the increasing risk of extinction are:

- The adoption of improved cultivars mainly in irrigated areas of o*ases* and mountains;
- Shifting towards barley in some rainfed areas because of recurrent drought.

The best strategies to conserve such diversity are:

- Collecting missions should be an ongoing process to collect and conserve the diversity *ex-situ* for use in breeding programs;
- Involvement of farmers to select landraces that perform at least as well as commercial cultivars is for sure the best and long-lasting efficient strategy to serve and conserve the diversity, knowing that quite a few old landraces were selected by farmers and those landraces performed even better that commercial cultivars.

The evaluation of old accessions preserved in INRA Genebank revealed that quite a few of them exhibited a multiple disease resistance, including stem rust.

A deep and thorough evaluation and characterization of a large sample of the old accessions preserved in INRA Genebank is of paramount importance.