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Agronomic and technological evaluation of a world safflower collection in Moroccan conditions

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Abstract
Safflower (*Carthamus tinctorius* L.) is a minor crop well adapted to semi-arid regions. In Morocco, a breeding programme has been launched recently in order to develop adapted varieties with high agronomic and technological potential. In 2006, a total of 212 accessions from different origins were collected and evaluated in 2 different locations for agronomic and technological characters. From this set, 181 accessions achieved successfully their growth and development cycle. The results of this study showed that a large variability existed between these accessions for the spinelessness, the height of plants, the earliness, the branching, the resistance to leaf rust, the thousand seed weight (TSW), the seed yield per plant and the oil content. Also, the location and the accession x location interaction effect was significant. The vegetal material exhibited, for all traits, highest potential in favourable environment (Allal Tazi) than in less favourable one (Douyet). The genotypes with high seed yield per plant were also characterized by a high TSW and were, in general, early flowering, dwarf and spiny. The genotypes having elevated seed oil content were those that had small seeds often associated with reduced hull. The accessions have been grouped into 5 pools on the basis of the most interesting traits: seed yield per plant, seed oil content, spinelessness, earliness and resistance to leaf rust. The nature and the composition of such pool should be confirmed after assessing the accessions for one more year. Selected genotypes from each pool will be used as elite parents in our safflower crossing programme.

Key words: Safflower – Morocco – accessions – evaluation – pools

Introduction

Even though safflower (*Carthamus tinctorius* L) is an old crop well adapted to semi-arid regions, it still remains a minor and underutilized oilseed crop. In 2005, world safflower acreage was around 814,000 ha, which constitute less than 0.5% of total area planted by oilseed crops (FAO, 2006). In Morocco, safflower cultivation was initiated in 1965 by planting 20 ha and the highest acreage ever registered was 3342 ha reached in 1990. After 1992, the safflower crop was abandoned for industrial, commercial and technical reasons. Seed yield and oil content remained very low due to the lack of performant varieties and poor management techniques used by farmers.

The safflower selection programme in Morocco was initiated in the 60's at INRA (National Institute for Agricultural Research). This programme was abandoned in the beginning of the nineties of the last century. The first breed Moroccan variety was Zitghani, developed in 1972 (Rohrmoser, 1975). Later, the selection work carried out by a private company led to the release of two new varieties, Cartafri (spiny type) and Cartamar (Spineless type), which were registered in 1999 (Hossini, 2002).

Recently, the Moroccan Ministry of Agriculture has called for the development of the crop through a global action plan including agricultural research. Thus, a new safflower breeding programme has been launched in 2006. The objective of this program is to release new spineless and productive safflower varieties with high technological value characterized by shorter vegetative cycle and higher seed yield and oil content than the existing varieties. In this frame, a large safflower collection has been obtained to constitute the initial germplasm. The aim of this work is to evaluate this collection in two locations for agro-morphological and technological characters.

Materials and Methods

Vegetal Material

A large safflower collection was obtained in 2005. It was constituted by 199 accessions provided by the ARS of the United States Department of Agriculture, 13 accessions from the gene bank of INRA-Settat (Morocco), 1 variety provided by CSIC-Cordoba (Spain) and 1 variety introduced from India. The Spanish variety (Rancho) and the Indian one (GK-7001) were used as checks. Table 1 summarizes the origin, the number of accessions per origin and the provenance of the accessions.

Methods

The vegetal material was planted at autumn (21 November 2005) in two locations representing different agroclimatique zones (INRA-experimental station of Allal Tazi in the Gharb region and INRA-experimental station of Douyet in the Saïs region) for morphological, agronomic and technological evaluation. The field experiment was conducted during 2005/06 using a completely randomised design. Each accession was grown in a single 3 m-length row. Inter and intra row spacing were 80 cm and 30 cm, respectively. Both checks were systematically planted after each 10 rows to control the field heterogeneity and to have a comparison basis. Data were collected on morphological traits (initial vigour, spinelessness level, plant height and branching), phenological trait (days from sowing to flowering), agronomic traits (seed yield by plant and thousand seed weight), technological trait (seed oil content by plant) and pathologic trait (leaf rust resistance). For computation of these parameters, a randomised sample of 5 plants by accession was taken. The initial vigour (IV) was defined on the accession basis following scoring scale from 1 (less vigorous) to 5 (most vigorous). The spinelessness level (SL) was determined on the plant basis following scoring scale from 1 (very spineless) to 4 (very spiny). The plant height (PH) was expressed in cm and branching indicates the number of principal branches per plant. The seed yield per plant (SYP) and the thousand seed weight (TSW) were expressed in g and seed oil content (SOC) was expressed in % of dry matter. Like the initial vigour, the leaf rust resistance (RR) was evaluated on the accession basis following scoring scale from 1 (very resistant) to 5 (very susceptible). The data gathered were statistically analysed using glm procedure of SAS statistical package (SAS Institute, 2001).

Table 1. Origin, number and provenance of the safflower collection accessions evaluated in Allal Tazi and Douyet during 2006.

Origin	Number of accessions	Provenance(1)
Iran	63	USDA
Egypt	33	USDA
USA	28	USDA
India	23	USDA
Morocco	13	MGB
Afghanistan	12	USDA
Pakistan	7	USDA
Palestine	5	USDA
Australia	5	USDA
China	5	USDA
Iraq	3	USDA
Kazakhstan	2	USDA
Ethiopia	2	USDA
Spain	2	USDA
Turkey	2	USDA
Canada	2	USDA
Kenya	1	USDA
Sudan	1	USDA
Syria	1	USDA
Kuwait	1	USDA
Unknown	1	USDA
Total	**212**	

(1) USDA: United States Department of Agriculture; MGB: Moroccan Gene Bank.

Results and discussion

From the 212 planted accessions, only 181 could achieve their growth and development cycle. Analysis of variance showed very high significant differences (P<0.001) between the accessions for all traits, except the initial vigour (Table 2). Also, there was a very high effect (P<0.001) of location and location x accession interaction on all studied characters except TSW, for which, both locations were comparable. A similar result was found in a previous study in Kenya evaluating 36 exotic safflower accessions for agromorphological characters such as yield per plant, branching and 100 seed weight (Mahasi et al., 2005). In the present work, a large variability was observed for all the characters. The initial vigour was higher at Allal Tazi (score 3.98) than at Douyet (score 2.80) with a variation from 2 to 5 at Allal Tazi and from 1 to 5 at Douyet, following the score scale described in the material and methods section. In the studied collection, we had very spiny accessions (score 4), spiny accessions (score 3), little spiny accessions (score 2) and spineless accessions (score 1). The registered mean value was 1.90 and 2.40 at Allal Tazi and Douyet, respectively, exhibiting a preponderance of little spiny accessions in the collection. Both checks, Rancho and GK7001, were very spiny. All the vegetal material showed a high stature (146 and 122 cm at Allal Tazi and Douyet, respectively) and a long vegetative cycle (153 up to 182 days from sowing to flowering at Allal Tazi and 160 up to 185 days at Douyet). The values exhibited by the checks for these traits, respectively, were 138 cm and 167 days for Rancho and 133 cm and 169 days for GK7001. In another USDA collection evaluated in Korean conditions, a variation from 53 to 128 cm for plant height and from 76 to 170 for days to flowering were recorded (Shim et al., 2004). More recently, in a study across 45 exotic and indigenous pure lines, the observed range for plant height was 61 to 86 cm while that for days from sowing to flowering was 116 to 134 days (Alizadeh and Carapetian, 2006). In our study and for Allal Tazi, the mean number of branches per plant was 29, varying from 19 to 46, while for Douyet, it was 24, varying from 10 to 34. Rancho had 27 and GK7001 had 25. Regarding the reaction to leaf rust, the accessions expressed, en general, an intermediate level of resistance to this disease (score 2.82 for Allal Tazi and 3.04 for Douyet). However very resistant (score 1) and very susceptible (score 5) genotypes were identified. Both checks were resistant (score 1.8 and 1.9 for Rancho and GK7001, respectively). In Allal Tazi conditions, the mean TSW was 34 g whilst the seed yield per plant was almost 44 g with a very large variation from 1.43 up to 119.38 g. The seed oil content fluctuated from 23.36 to 47.53%, having a mean value of 31%. In Douyet conditions, the mean TSW was 36.61 g whilst the seed yield per plant was almost 32 g with a large variation from 10.43 up to 74.41 g. Rancho had a TSW of 41.4 g and a SYP of 62.95 g while GK7001 had, respectively, 38.3 g and 54.4 g for these characters. The seed oil content ranged from 19,90 to 46,21%, having a mean value of 27.15%, compared to 34% for Rancho and 31.1% for GK7001. In previous studies, the observed range for oil content was 27 to 40% (Cazzato et al., 2001), 23 to 34% (Alizadeh, 2005) and 21.4 to 31.7% (Alizadeh and Carapetian, 2006). Because of the most favourable conditions in Allal Tazi, the accessions exhibited higher potential in this location than in the other (Douyet). Nevertheless, in all cases, a large genetic variability was found across these accessions allowing selection possibilities. On the other hand, significant differences were observed between plants among accessions for spine level, plant branching and seed oil content, revealing the heterogeneity of the accessions and the possibility to select performant genotypes for these traits within the accessions.

Table 2. Analysis of variance (Mean square and significance level of differences) for agro-morphological and technological traits of 181 safflower accessions evaluated in Allal Tazi and Douyet during 2006.

Source of variation	IV[1]	SL	PH	DSF	NBP	LRR	TSW	SYP	SOC
Location	597,75	38,74	223640	5434,25	10128	48,91	86.18	46314.51	2893.07
(L)	***[2]	***	***	***	***	***	ns	***	***
Accession	3.04	10,79	1477,43	160,81	157,13	6,32	457.41	1497.59	60.55
(A)	ns	***	***	***	***	***	***	***	***
S x A	3,15	1,26	253,35	31,31	56,85	3,82	64.66	1241.34	12.96
	***	***	***	***	***	***	***	***	***
Plant (A)	---	0,34	104,48	3,48	34,75	---	36.74	779.63	9.64
		***	ns	ns	*		ns	ns	**

(1) IV initial vigour, SL spinelessness level, PH plant height, DSF days from sowing to flowering, NBP number of branches per plant, LRR leaf rust resistance, TSW 1000 seed weight, SYP seed yield per plant, SOC seed oil content.
(2) *, ** and *** significant at 0.05, 0.01 and 0.001 levels, respectively. ns not significant.

Table 3 shows coefficients of correlation as well as significance level for studied characters. The higher coefficient was that existing between plant height and days to flowering (0.67), indicating that the high genotypes are late. Such genotypes are generally spineless and have a low TSW. In fact, there was a negative and significant correlation between plant height and spines level (-0.52) and between plant height and TSW (-0.39). There was also a negative and significant association between TSW and branching (-0,43). The TSW exhibited the higher positive and significant association with the seed yield per plant (0.36). Number of days from sowing to flowering was negatively and significantly associated with the seed yield per plant (-0.28). This indicates that the early material is often characterized by a high seed yield which is explained by a high TSW. However, TSW showed a negative and significant association with seed oil content (-0.16), indicating that this latter might decrease with seed size. Seed yield was affected positively by TSW, which is in concordance with a finding of Bidgoli et al. (2006). These authors reported that TSW had a substantial direct effect on enhancement of seed yield. The significant negative relationship between seed yield per plant and days to flowering suggests that seed yield was higher for early material than for late one. This correlation was also reported by Alizadeh and Carapetian (2006). Previous studies showed that the early material was often dwarf and had a high seed weight (Pascual-Villalobos and Alburquerque, 1996; Alizadeh and Carapetian, 2006). This was also observed in our experiment. This preliminary result, which should be confirmed next year, suggests that seed yield could be improved by selecting for early flowering and dwarf genotypes. Unfortunately, such genotypes are in general spiny, which forces an additional effort to introduce the spineless character into this interesting material. The correlation between TSW and oil content was negative and low. Similar result was found by Alizadeh and Carapetian (2006). This negative association could be due rather to the indirect effect of hull content than to direct effect of seed size (Rao et al., 1977).

Table 3. Correlations between different traits of 181 safflower accessions evaluated in Allal Tazi and Douyet during 2006.

	IV	SL	PH	DSF	NBP	RR	SYP	TSW	SOC
IV[(1)]	1,00	0,07ns[(2)]	-0,11ns	-0,18*	-0,12ns	-0,03ns	0,06	0,15*	-0,02
SL		1,00	-0,52***	-0,38***	-0,36***	0,11ns	0,22**	0,30***	0,06
PH			1,00	0,67***	0,38***	-0,15*	-0,12ns	-0,38***	0,10ns
DSF				1,00	0,32***	-0,19**	-0,28***	-0,42***	0,14ns
NBP					1,00	-0,08ns	0,00ns	-0,43***	0,05ns
RR						1,00	-0,10ns	0,10ns	0,04ns
SYP							1,00	0,36***	-0,04ns
TSW								1,00	-0,16*
SOC									1,00

(1) IV initial vigour, SL spinelessness level, PH plant height, DSF days from sowing to flowering, NBP number of branches per plant, LRR leaf rust resistance, TSW 1000 seed weight, SYP seed yield per plant, SOC seed oil content.
(2) *, ** and *** significant at 0.05, 0.01 and 0.001 levels, respectively. ns not significant.

The evaluated safflower collection exhibited a large variability for economically important traits such as seed yield, oil content, leaf rust resistance, spinelessness and earliness. On the basis of these traits, we have constituted 5 different pools. Each pool was formed by homogeneous and performant accessions with regard to a specific trait. Thus, we have pool 1 with high seed yield per plant (> 55 g), pool 2 with high seed oil content (> 35%), pool 3 of rust resistant accessions (score < 2), pool 4 with spineless material (score = 1) and pool 5 of early flowering accessions (days from sowing to flowering < 160). The nature and the composition of these pools will be confirmed after assessing the present collection for one more year at the same locations. From each pool, stable genotypes will be selected to constitute elite parents in our future crossing programme. The crosses should be achieved between genitors belonging to different pools in order to develop germplasm combining some of the traits mentioned above.

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