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CONTRIBUTION TO THE EVALUATION OF *Citrullus colocynthis* (L.) SCHRAD AS POTENTIAL BIODIESEL FEEDSTOCK: SEED YIELD, OIL CONTENT AND YIELD COMPONENTS

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Abstract

Citrullus colocynthis is a perennial her baceous species in the Cucurbitaceae family widely distributed in the Sahara Arabian desert in Africa and the Mediterranean region. This plant has a natural adaptation to drought and several studies have reported that this plant has a great potential for adaptation to drought with a tolerance to water deficit. C. colocynthis has been garnering interest in recent times as a potential biodiesel feed stockcrop due to its high seed oil content. The variability of seed and oil yields were investigated for 12 accessions collected in different localities in Morocco and analyze during two consecutive trials. The measured traits are: seed number (SN), seed weight (SW), weight of 100 seeds (W100), seed oil content (OC), seeds yield (SY) and oil yield (OY). The seed oil content ranging between 17 and 24% of seed weight. The extrapolated seed yield among the accessions ranged from 156 to 816 kg/ha, with an overall mean of 413 kg/ha. The oil yield varied between 35 to 172 kg/ha. The results of anova (GLM) show significant and very highly significant differences between the accessions according to the characters measured.

Key words: *Citrullus colocynthis, seed oil content, seeds yield, oil yield, Morocco.*

INTRODUCTION

Citrullus colocynthis (L.) Schrad (2n = 22), closely related to domesticated watermelon (*Citrullus lanatus* var. *lanatus*) (Chomicki & Renner, 2015), is a very drought-tolerant perennial herbaceous species in the *Cucurbitaceae* family.

It is a wild native plant growing in arid areas, widely distributed in the Sahara-Arabian desert in Africa and the Mediterranean region (Si et al., 2010; Wang et al., 2014). In recent years, the development of new oil seed crops that can be used as alternatives to conventional plants has generated a lot of interest and *C. colocynthis* is one of the plants that is able to adapt to arid conditions.

This plant has a natural adaptation to drought and several studies have reported that this plant has a great potential for adaptation to drought with a tolerance to water deficit (Hassan et al., 2012; El Madidi et al., 2017; Verma et al., 2017). *C. colocynthis* being an exceptionally hardy plant with a potential for use as biodiesel feedstock (Giwa et al., 2010; Bello and Makanju, 2011). The plant was also shown to be rich in nutritional value with high protein contents and important minerals as well as edible quality of seed oil (Hussain et al., 2014).

MATERIALS AND METHODS

12 accessions of *C. colocynthis* collected from different regions from Morocco (Figure 1). The trial was carried out during 2 growing seasons 2016-17 and 2017-18 at the experimental farm of Sidi Bibi (30° 15' 00" N, 9° 30' 36" W), following a randomized block experimental design with 3 replicates for each trial. The measured traits are: seed number per plant (SN), seed weight per plant (SW), weight of 100 seeds per plant (W100), oil content of seed (OC), Seed yield (kg/ha) and Oil yield (kg/ha). The lipid components of the *C. colocynthis* seeds were subsequently extracted with n-hexane using a Soxhlet apparatus at 45-50°C for 6-8 h until the extraction was completed. The crushed seeds (approximately 400 g) of *Citrullus colocynthis* were placed in a Soxhlet apparatus and then extracted with 300 mL n-hexane for 7 hours on a water bath. Lipid fraction was extracted in a Soxhlet apparatus for 16 h at 60°C. The solvent was evaporated, and the lipid fraction residues were weighed.

Data were analyzed by the GLM procedure of SAS with the following statistical model:

$Y_{ijk} = m + A_i + B_j + AB_{ij} + C_K + E_{ijke}$.

Where: A_i: effects of accessions, B_j: effects of years, AB_{ij}: effects of interaction accessions years, C_K: effects of blocs and E_{ijke}: residual error. Statistics analysis was carried out using computer software SAS version 9.3 (SAS Institute Inc., 2010).

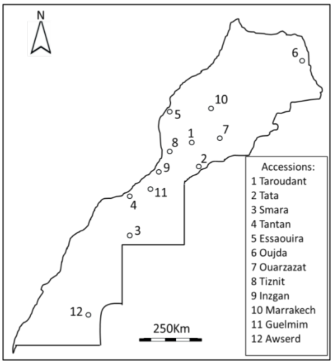

Figure 1. Origin of accessions of *Citrullus colocynthis* (L.) Schrad collected in several localities in Morocco

RESULTS AND DISCUSSIONS

Analysis of the data shows a high degree of variability with the coefficient of variation (CV) ranged from 7.65 % to 67.34 %. The seeds weight per plant has the highest CV and the values are ranged from 4.09 to 198.40 grams, while for the seeds number the values vary from 121 to 1467 seeds per plant. The seed yields ranging between 155.78 and 815.76 kg per hectare and the oil yield varies between 35.27 and 171.71 kg/hectare while the seed oil content (OC) shows the lowest CV and the minimum and maximum are respectively 17.1 and 24.3 % (Table 1).

Table 1. Descriptive statistics for the measured characters

	m	Min	Max	SD	CV(%)	SE
SN/P	770.08	121.00	1467.00	510.05	66.23	19.01
SW/P	42.66	4.09	198.40	28.73	67.34	1.07
W_{100}	5.562	3.01	9.63	0.772	13.88	0.016
SY(Kg/ha)	419.87	155.78	815.76	159.94	39.09	18.85
OC (%)	21.41	17.10	24.29	1.64	7.65	0.19
OY(Kg/ha)	89.84	35.27	171.70	34.99	38.96	4.12

SN/P: seed number per plant, SW/P: seed weight per plant (g), W_{100}: weight of 100 seeds SY: Seeds Yield (kg/ha), OY: Oil Yield (kg/ha) and OC: oil content, m: mean, Min: Minimum, Max: Maximum, SD: Standard Deviation, CV: Coefficient of Variation and SE: Standard error.

Table 2. Results of GLM Anova (Fisher-Snedecor values and significant levels)

SV	SN	SW	W_{100}	OC	SY	OY
Accessions	12.55 ***	10.74 ***	13.50 ***	9.52 ***	12.20 ***	6.67 ***
Years	33.82 ***	15.93 ***	27.99 ***	13.55 **	6.24 **	8.71 **
Acc x Y	1.50	0.95	3.16 *	2.61 *	3,29 *	0.66
Blocs	2.31	2.94 *	2.25	1.24	1.40	1.75

***, **, *: was significant at 0.001, 0.01 and 0.05 level respectively.

The analysis of variance (ANOVA) indicated high statistically significant differences among the 12 accessions for all the characters analyzed (Table 2). Highly significant diferences are also observed between the trials of the two successive years. The interaction accessions x years was significant for SY, W100 and OC.

Table 3. Mean values and classification into homogeneous groups of the 12 accessions of *Citrullus colocynthis* (L.) Schrad

	SN	**SW**	**SY**	**OC**	**OY**	**W_{100}**
A1	723.8 bc	40.51 bcd	405.09 abc	21.02 bc	84.88 abc	5.59 cd
A2	1084.28 ef	58.67 fj	586.67 de	21.04 bc	123.11 de	5.45 bc
A3	643.25 abc	34.57 abc	346.91 ab	23.19 e	80.43 ab	5.46 bc
A4	517.32 a	29.36 a	289.05 a	21.97 cde	63.43 ab	5.72 ce
A5	918.33 de	49.24 def	375.69 ab	21.09 bc	78.2 ab	5.36 b
A6	774.27 cd	44.4 cde	451.48 bcd	19.25 a	87.56 abc	5.84 e
A7	650.72 abc	36.91 abc	369.09 ab	20.02 ab	73.97 ab	5.69 ce
A8	566.48 ab	30.43 ab	304.28 ab	21.78 cd	66 ab	5.24 a
A9	814.92 cd	42.25 cd	418.76 abc	22.93 cde	96.25 bcd	5.18 a
A10	539.77 ab	30.06 ab	306.89 ab	20.12 ab	61.21 a	5.78 ce
A11	1100.45 f	62.4 j	640.69 e	22.96 de	146.97 e	5.62 cd
A12	905.84 d	52.99 fj	543.90 cde	21.53 c	116.11 cde	5.82 ce

Means within columns with different superscript are significantly different ($p < 0.01$) using the Ducan New Multiple Range Test (DMRT).

The mean values of the variables measured and the distribution of the 12 accessions into homogeneous groups are given in Table 3. For seed yield, average values were grouped into 5 homogeneous groups and ranged from 289.05 kg/ha (accession 4) to 640.7 kg/ha (accession

11). For oil yield, the average values were arranged into 5 homogeneous groups and varied between 61.2 kg/ha (accession 10) and 146.97 kg/ha (accession 11). 7 homogeneous groups are observed for the seeds weight per plant (SW) and the lowest value is recorded for A4 while the highest value is recorded for A11. For the seeds number per plant (SN), the means values vary from 517 to 1100 seeds per plant which are measured respectively in A4 and A11.

Table 4. Ranking order for different characters of the 12 accessions

	SN	SW	SY	OC	OY	W_{100}	AR
A1	7	7	6	8	6	7	6.83
A2	2	2	2	9	2	9	4.33
A3	9	9	8	1	7	8	7.00
A4	12	12	11	4	11	4	9.00
A5	3	4	7	7	8	10	6.50
A6	6	5	4	12	5	1	5.50
A7	8	8	12	11	9	5	8.83
A8	10	10	10	5	10	5	8.33
A9	5	6	5	3	4	12	5.83
A10	11	11	9	10	12	3	9.33
A11	1	1	1	2	1	6	2.00
A12	4	3	3	8	3	2	3.83

AR : Average Rank

The order of classification of the 12 accessions is presented in Table 4 which shows that the classification of the accessions according to the variable analysed. The lowest averages rank values are observed for A11, A12 and A2 while the highest averages values are attributed to A10, A4, A7 and A8. Accession A11 recorded the lowest average ranking, it is the first in terms of SN, SW, SY and OY, and second for OC. The highest average rank value is observed for A10, it is the 12th for OY, 11th for SN and SW, 10th for OC and 9th for SY.

The seed yield values obtained in this study under semi-arid conditions without any fertilizer and under conditions of limited irrigation, remain relatively low compared to those potentially obtained under optimal growing conditions. The seed yield values obtained in this study under semi-arid conditions without any fertilizer and under conditions of limited irrigation, remain relatively low compared to those potentially obtained under optimal growing conditions. The authors of a study conducted on the production of *Citrullus colocynthis*, reported that production can reach 4400 kg of seeds and 1000 to 1175 L/ha of colocynth vegetable oil in rainy conditions (Mertia & Gupta, 1994). With plant density of four plants per m^2, the extrapolated annual seed yield among the accessions of *Citrullus colocynthis* ranged from 0.47 to 14.95 tons/ha, with an overall mean of 5.17 tons/ha (Menon et al., 2016). In the desert in Pakistan, some accessions of *C. colocynthis* developed an extensive root system despite of receiving only receiving only 35-40 mm of rainfall, can be produced as much as 1-1.5 t of seed/ha, but as much as 40-fold more if rainfall is higher (Mahajan et al., 2013).

This plant has the potential to be used for grain production for oil extraction, especially under difficult conditions on arid and semi-arid lands and the exploitation of the natural variability could be used for the selection of accessions that have good oil yields in limited growing conditions (El Madidi & Benmoumou, 2020). To reduce their energy dependence and decrease their carbon emissions, many countries have encouraged the use of biofuels, but competition between edible oil and fuel needs can lead to higher prices for essential foodstuffs and global disproportion in fuel consumption and for the food industry and market demands. Knowing that the use of all edible oils for the production of biodiesel will not be enough to meet the global demand for biofuel (Kumar & Sharma, 2011; Taufiq-Yap et al., 2011). Therefore, there is a need for an inexpensive, inedible raw material such as *Citrullus colocynthis* oil for the production of biodiesel. This plant being desert shrub and semi-xerophytic in nature, require less water and can tolerate saline as well as alkaline soils and that grows in many countries in the arid or semi-arid lands and its seeds are rich in oil, which can encourage their sustainable agriculture to produce economical biodiesel at a competitive price (Elsheikh et al., 2014).

CONCLUSIONS

The results obtained in this study show that this plant has good potential to be used for the seeds production for oil extraction, especially in difficult conditions in arid, semi-arid and wastelands. The great variability in seeds and oil yield suggests that better yields can be obtained by analyzing the best growing conditions and selecting the best accessions for a yield with good tolerance to different abiotics stress.

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