Alternative Crops for Adaptation to Climate Change: The Importance of Conserving the Diversity of *Lathyrus cicera* L. Landraces Adapted to the Morocco Mountains [†]

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[†] Presented at the 1st International Electronic Conference on Agronomy, 3–17 May 2021; Available online: <https://sciforum.net/conference/IECAG2021>.

Abstract: A Global climate change has raised serious concerns about food security and the sustainability of agriculture, particularly in developing regions of the world. In response to these concerns, attention should be called to the global importance of conservation of some neglected and underutilized crops, such as *Lathyrus* species, which are nutrient-rich and already adapted to harsh environments and low-input agriculture. *L. cicera* L., known in Morocco as ‘ikiker’, ‘kiker’ or ‘ichicher’, is marginally cultivated in the region. Landraces of this crop species, which are maintained locally by traditional agricultural practices, correspond to ecotypes adapted to local agroclimatic conditions. We have surveyed the traditional cultivation sites of this crop to identify specific associated agroecosystems in the Middle and High Atlas Mountains of Morocco. We have evaluated the diversity of ecotypes of *L. cicera* L. by a set of characters associated with the socioeconomic and agromorphological aspects of their cultivation. The results confirmed that their cultivation is very old in the area, and that its maintenance until today is important as the local farmers have started to master the uses for human and animal food. In addition, from a biology point of view, we have demonstrated the existence of variability depending on the trait considered but which demonstrates a differentiation between the ecotypes. From adaptive potential of these ecotypes with respect to tolerance to aridity and increased temperatures, the ecotypes studied showed promising prospects for selection. Thus, despite the limitation of the territory and the regression of the culture, the studied ecotypes have a very interesting stand. This result can be explained by cultural practices. These ecotypes are maintained in traditional agroecosystems which play the role of conservatory of the neglected resources. Therefore, the conservation of these genetic resources depends on the conservation of the traditional agroecosystem and local knowledge.

Keywords: *Lathyrus cicera* L.; phenotypic diversity; alternative culture

Citation: Fatehi, S.E.; Ater, M.; Hmimsa, Y. Alternative Crops for Adaptation to Climate Change: The Importance of Conserving the Diversity of *Lathyrus cicera* L. Landraces Adapted to the Morocco Mountains. *Biol. Life Sci. Forum* **2021**, *3*, 21. <https://doi.org/10.3390/IECAG2021-09734>

Academic Editor: Gianni Bellocchi

Published: 1 May 2021

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1. Introduction

At the global level, variations in climatic events have influenced all regions, and even, this trend is likely to continue or even accelerate in the future, with probably serious but variable consequences on quality and agricultural productivity in the world [1–5]. Indeed, the impacts of climate change can strongly claim the agricultural sector, especially the component of production and food supply, either directly or indirectly [6], thus threatening global food security [7–9]. In addition, the situation is more alarming if we consider the importance of modern monoculture systems, which are more ecologically homogeneous than polyculture systems [10–12]. As a result, the drastic reduction in crop diversity has threatened global food production, including three food crops (wheat (*Triticum* spp.), Rice (*Oryza* spp.) and maize (*Zea mays* L.)) which provide more than half of the food energy

consumed by humans [13]. Faced with such a situation, minimizing the loss of plant genetic resources, increasing the sustainability and resilience of agricultural systems have been identified as major pillars [14,15]. Traditional agro-ecosystems are a good example of conservation of agro-biodiversity and livelihood face to environmental and economic constraints, i.e., the ability of agroecosystems to maintain functioning and productivity under stress and shock conditions [16–18]. This study aims to identify and characterize crops that are practiced in traditional agroecosystems. *L. cicera* L. is an example of a marginalized crop considered neglected and underutilized. It is an ancient legume native to the western Mediterranean [19,20]. In Morocco, the extent of its cultivation is very limited to the geographical area of the Middle and High Atlas, representing its last refuge. However, there is renewed interest in this species with adaptation and introduction trials in different regions of the world. This interest coincides with the context of climate change and the identification of alternative crops. These crops must be adapted to the difficult conditions foreseen by the different climate scenarios and models. This challenge highlights the importance that we place on this culture through this study.

2. Material and Methods

2.1. Study Area

The plant material was collected in the main cultivation area of *L. cicera* within the traditional mountain agroecosystems of the High and Middle Atlas (Table 1). Pods were sampled from randomly selected individuals along a diagonal line across the field. Sampling was carried out in the spring, when the pods and seeds were mature, just before harvest, from which 13 ecotypes were collected.

Table 1. Location of sampling sites for the different ecotypes of *L. cicera*.

Locality Name	Longitude East	Latitude North	Altitude (m)
Tissa	06°32.052	31°56.421	1400
Souk nouzdir	06°29.293	31°52.368	1377
Bernat (1)	06°31.167	31°50.724	1402
Bernat (2)	06°31.087	31°50.087	1653
Tamarzoukat	06°32.792	31°56.452	781
Bernat (3)	06°31.366	31°51.116	1407
Ouaoura	06°31.874	31°52.101	1075
Ait aarfa	06°34.308	31°59.147	1354
Ikharkhoud	06°33.498	32°01.172	848
Arbalou-n bouali	06°32.026	32°03.673	460
Ait ali-o- mhand	06°26.296	32°06.584	451
Ait halwan	06°24.247	32°07.297	1019
Iaamouman	06°21.422	32°10.212	507

2.2. The Capacity of Germination

For each ecotype, 30 seeds were used for germination test. The seeds used were disinfected by Hypochlorite of sodium (1%) before being distributed among the Petri dishes, then they were soaked in distilled water and placed in the dark. Daily monitoring was adopted in order to assess the percentage of germination (PG), the precocity (PR: speed of the onset of germination) and the germination time (GT: time necessary to reach the maximum germination capacity).

2.3. Seed and Pod Biometry

The morphological parameters of the seed and pod are a trait for the assessment of the diversity and polymorphism of *L. cicera* ecotypes. Thus, 12 characters were measured: 4 at seed level (Seed length (SL), Seed width (SWD); Seed length/Seed width (SL/SWD); Seed weight (SWG)) and 8 at pod level (Pod length Total (PLT); Pod length Basal (PLB); Pod length Total/Pod length Basal (PLT/PLB); Pod length Total-Pod length Basal (PLT-PLB);

Pod width (PWD); Pod length Total/Pod width (PLT/PWD); Pod weight (PWG); Number of seeds per pod (NSP)).

2.4. Data Processing

Descriptive statistics and analysis of variance (ANOVA) were performed with the XLSTAT software (version 2010). The hierarchical classification (Euclidean distance and UPGMA clustering method) was carried out using the NTSYSpc software (1.05).

3. Results

3.1. Precocity, Duration and Germination Capacity

Regarding the precocity, the ecotypes of *L. cicera* are revealed early (Table S1, Supplementary Material). The germination of all ecotypes was noted from the second day (Figure 1). For this, the germination time varied between 72 and 96 h, however, all the ecotypes showed a short germination time of 72 h except Iaamouman ecotype which required a germination time of 96 h. Regarding the germination capacity, after 48 h, the germination percentage varied between 43% (Souk nouzdir) and 10% (Tamarzoukat, Ouaoura, Ikharkhoud and Iaamouman), however, after 72 h, it varied between 90% and 100%; 3 ecotypes had a germination percentage of 100% (Ouaoura, Ikharkhoud and Ait ali-o-mhand) and 7 ecotypes which achieved 96% germination (Tissa, Souk nouzdir, Bernat 1, Ait aarfa, Arbalou-n bouali, Ait halwan and Iaamouman), one ecotype reached 93% (Bernat 3) and two ecotypes resulted in 90% germination (Bernat 2 and Tamarzoukat). Nonobstant, Iaamouman did not reach 100% germination until after 96 h.

Figure 1. The germination capacity of the 13 ecotypes of *L. cicera*.

3.2. The Biometrics of the Seed

The results relating to the data collected from measurements carried out on the seeds of the various ecotypes collected showed significant variations within and between the various ecotypes (Figure 2, Table 2). The analysis of variance for the different traits measured showed a very highly significant difference ($p < 0.0001$) which is the result of morphological diversity between individuals of these ecotypes. This difference is expressed more with a

very high F for the characteristics relating to the size than for the weight and the shape of the seeds.

Figure 2. Presentation of the parameters of seeds of *L. cicero*. (A) Seed length; (B) Seed width; (C) Seed length/Seed width; (D) Seed weight.

Table 2. Results of the one-way analysis of variance of the various parameters of seeds of *L. cicera*.

Ecotype	SL (mm)	SWD (mm)	SL/SWD	SWG (g)
Mean $\pm$ SD	5.62 $\pm$ 0.54	5.34 $\pm$ 0.57	1.05 $\pm$ 0.06	0.08 $\pm$ 0.03
CV	9.56	10.75	5.54	44.06
F	37.805	46.190	6.755	10.608
p	<0.0001	<0.0001	<0.0001	<0.0001

The SL mean is 5.62 mm; the smallest seeds (5.08 mm) are from Souk nouzdir and the larger seeds (6.08 mm) are from Ait halwan. For SWD, the values per ecotype vary between 5.85 mm (Ait halwan) and 4.75 mm (Souk nouzdir) with an average of 5.34 mm. Thus, the seeds of large size are those of Ait halwan and smaller sizes are that of Souk nouzdir, while the seeds of other ecotypes are included in the interval between the sizes of these two populations. The SL/SWD ratio expressed somewhat the general shape of the seed and showed poor differentiation at this level with a low coefficient of variation (5.54%) compared to SL and SWD. Indeed, the values recorded by the SL/SWD ratio varied between 1.04 (Ait aarfa, Ikharkhoud, Arbalou-n bouali, Ait ali-o-mhand, Ait halwan and Iaamouman) and 1.08 (Tissa and Souk nouzdir) with an average of 1.05. Regarding SWG, a significant variation was noted with a coefficient of variation of around 44.06%. It varied between 0.1 mg (Ait halwan) and 0.01 mg (Arbalou n bouali) with an average of 0.08 mg. Thus, the seed characters showed a certain level of polymorphism in which the seeds differed more in size and weight than in shape.

3.3. The Biometrics of the Pod

The data collected from the measurements carried out on the pods of each ecotype showed very highly significant to significant differences depending on the trait studied

(Figure 3, Table 3). Thus, we noted that the characters can be classified in decreasing order of differentiation according to the value of: $PLB = 29.78$, $PWG = 27.11$, $PLT = 25.72$, $PWD = 22.1$, $PLT/PWD = 7.53$, $PLT/PLB = 4.97$, $NSP = 2.27$, $PLT-PLB = 1.77$. It therefore clearly appears that the pods of the ecotypes differ mainly in size and weight than in shape and number of seeds per pod.

Figure 3. Presentation of the parameters of pods of *L. cicero*. (A) Pod length Total; (B) Pod length Basal; (C) Pod length Total/Pod length Basal; (D) Pod length Total-Pod length Basal; (E) Pod width; (F) Pod length Total/Pod width; (G) Pod weight; (H) Number of seeds per pod.

Table 3. Results of the analysis of variance with a classification criterion of the different parameters of the pods of *L. cicera*.

Ecotype	PLT (mm)	PLB (mm)	PLT/PLB	PLT-PLB	PWD (mm)	PLT/PWD	PWG (g)	NSP
Mean $\pm$ SD	36.08 $\pm$ 3.62	29.16 $\pm$ 3.33	1.24 $\pm$ 0.05	6.92 $\pm$ 1.36	8.18 $\pm$ 0.75	4.41 $\pm$ 0.34	0.42 $\pm$ 0.10	4.55 $\pm$ 0.62
CV	10.05	11.43	4.32	19.69	9.19	7.8	23.46	13.8
F	25.72	29.78	4.97	1.77	22.1	7.53	27.11	2.27
p	<0.0001	<0.0001	<0.0001	0.05	<0.0001	<0.0001	<0.0001	0.008

The mean of PLT is 36.08 mm, it is longer (40.09 mm) in Aït halwan, and smaller (31.57 mm) in Tissa. However, the average PLB recorded is 29.16 mm, varying between 33.22 mm; the longest at Aït Halwan; and 24.90 mm; the smallest in Tissa. The mean values of the ratio (PLT/PLB) and the difference (PLT-PLB) are, respectively, 1.24 and 6.92 corresponding to more or less slivered shape. The average PWD of the fruit was 8.18 mm, the variation limits of which were 7.28 mm and 9.1 mm. For PWG, the average is of the order of 0.42 mg, which showed a significant level of differentiation with a coefficient of variation of 23.46%; the lightest pods are those of Tissa (0.32 mg) and the heaviest are those of Aït halwan (0.57 mg). However, the NSP showed very little variation, with an average of 4.55 and a coefficient of variation of 13.8%.

3.4. Hierarchical Classification

A hierarchical classification of 13 ecotypes was carried out using the mean values of all quantitative variables (Figure 4). It represented the similitudes among the different ecotypes based on Euclidean distance. Two groups are distinguished according to a size gradient. Group 1 is formed mostly by ecotypes with large size, heavy seeds and pods. Group 2 includes ecotypes with smaller seeds and pods. Some morphologically highly differentiated ecotypes ascribed to group 1 (Aït aarfa and Ikharikhoud) and group 2 (Tamarzoukat, Bernat 1 and Souk nouzdir) are located in the same area and belong to the same watershed. There is a limited relationship between the observed size gradient and geography, with only a slight tendency for the size of the pods and seeds to decrease from north to south.

Figure 4. Distance dendrogram between 13 ecotypes of *L. cicera* obtained by the method of unweighted pair groups with arithmetic means (UPGMA) based on a paired Euclidean distance matrix calculated on morphological markers.

4. Discussion

Despite the small number of agromorphological characters used in this study (seed, pod and germination), significant variability was observed in ecotypes of *L. cicera*. The interest and importance of this variability are particularly interesting although the territory in which culture is present is small and relatively delimited. From a socio-economic point of view, the observations made in the field and the discussions with the farmers confirmed the indigenous origin of the ecotypes cultivated and maintained locally, from a stock of seeds traditionally renewed by the peasants, these practices justify the variability which has been highlighted. Indeed, the presence of a significant morphological variability between fields can be related to the mode of seed conservation. In addition, the almost total absence of seed exchanges between the different growing regions helps maintain variability between fields. Each ecotype evolves in isolation from the others, supporting the differences observed over generations. However, further study for other agromorphological characters affecting the adult plant and its productivity could then provide a better insight into the extent and importance of this morphological variability.

5. Conclusions

The study showed the existence of a significant diversity between the ecotypes of *L. cicera* in Morocco. This phenotypic diversity has been demonstrated by a small number of morphological markers (seed and pod). This evaluation must be extended first by other agromorphological characters, and which concerns the whole plant and its productivity and secondly by genetic markers for more efficient estimation of genetic diversity. These studies are essential in this culture. Characterization is the first step towards conservation. Subsequently, in a region where culture continues to decline, we must highlight the urgency of putting in place strategies to encourage the conservation of this heritage. The best strategy seems to us to be in situ conservation in a peasant environment by encouraging the maintenance of traditional cultures.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/IECAG2021-09734/s1>, Table S1: presentation of precocity (PR), germination time (GT) and percentage of germination (PG) of the 13 ecotypes of *L. cicera*.

Author Contributions: Conceptualization, S.E.F. and Y.H.; methodology, S.E.F. and M.A.; software, S.E.F.; validation, S.E.F., M.A. and Y.H.; formal analysis, S.E.F., M.A. and Y.H.; investigation, S.E.F., M.A. and Y.H.; resources, S.E.F., M.A. and Y.H.; data curation, S.E.F.; writing—original draft preparation, S.E.F.; writing—review and editing, Y.H.; visualization, Y.H.; supervision, Y.H.; project administration, S.E.F.; All authors have read and agreed to the published version of the manuscript.

Acknowledgments: The authors thank the farmers of the various villages who contributed to the realization of this study.

Conflicts of Interest: The authors declare no conflict of interest.

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