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RESEARCH ARTICLE

Exploring agro-morphological diversity of Algerian hot pepper (*Capsicum annuum* L.) accessions using multivariate statistics

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ABSTRACT

Pepper is an inevitable constituent in the diets of Algerian population. Unfortunately, the local landraces are endangered by both genetic erosion and pollution. This study aimed to perform agro-morphological characterization of hot peppers (*Capsicum annuum* L.) accessions. Twenty one accessions collected from the east and south of Algeria were evaluated for 24 quantitative and 38 qualitative morphological characters under green-house conditions. The trial was conducted in a Randomized Complete Block Design (RCBD), with four replicates at the experimental station of the Department of agronomical sciences of Biskra University in Southeast Algeria. Significant variations in most of the traits were strikingly demonstrated using variance analysis and coefficients of variation and the number of modalities, frequencies and Shannon–Weaver diversity index (H′) values for the quantitative and qualitative characters respectively indicating the heterogeneity of the studied accessions. The correlations between the studied quantitative variables showed that the yield parameters were correlated with the variables related to the vegetative part of the plant. The first five PCs explained 76.877 % of the total variation and identified the most discriminant variables related particularly to yield and fruit characteristics contributing to PC1: fruit width; fruit index; fruit weight, number of locules; placenta length, pedicel length, anther length, leaf width and plant height/stem length ratio. For several qualitative traits, an important degree of variability was observed. The first factorial dimension explained 42.5% of the variance and was mostly associated with: plant height; growth habit; flower position; corolla shape; number of flower per axil and fruit shape at pedicel attachment and at blossom end; calyx margin. Cluster analysis of the combined data grouped the pepper landraces into four clusters regardless of the localities and the closest accessions belonged to different localities and/or provinces. This study notably confirms the presence of considerable genetic diversity within and between accessions of hot pepper in Algeria and provides a basis for its active conservation and future selection to develop improved local pepper populations.

Keywords: Algeria; *Capsicum annuum* L.; Genetic resources; Phenotypic variation; Qualitative and quantitative characters

INTRODUCTION

Capsicum annuum is one of the five domesticated species of *Capsicum* genus. Because of its high commercial advantage, it has been popular and of great interest since antiquity (Padilha et al., 2016; Barboza et al., 2019). The consumption of pepper occurs throughout the world in various ethnic groups, adding flavor, aroma, and color to food (Ornelas-Paz et al., 2013).

Pepper is an unavoidable component of the Algerian population's diet. It is consumed in various forms including fresh consumption, dry powder and pasta. It is grown across the whole country in a different of settings varying from small-scale subsistence farming to large-scale commercial enterprises. Nevertheless, there are a few records on hot pepper landraces acreages and yield, which do not accurately reflect the crop's current economic importance. In Algeria, 2 400.1 hectares are annually cultivated with chili peppers and total production is estimated at 174 234.1 tons. Yield tends to vary considerably depending on numerous factors mainly the origin of hot pepper variety planted which is closely related to the crop system. In Biskra province for example, yield records ranging from

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3 t/ha in open filed where landraces are used to 75.8 t/ha in protected area exclusively sown with introduced hybrid varieties (MADR, 2020).

As far as we know, no systematic strategies have been made in Algeria to retrieve these precious resources, which is facing many challenges mainly genetic pollution and genetic erosion. In Biskra province, the growers of local pepper observed these latest years a decline in its pungency in some localities allowing us to put forward the hypothesis of ongoing processes of genetic contamination due to the cross-pollinations occurred with introduced sweet and hot pepper hybrid closely sown. Our assumption is supported by the fact that the out crossing rate in *Capsicum* varies greatlyfrom 2 to 90% (Tanksley, 1984; Pickersgill, 1997) and the interspecific crosses compatibility between accessions of C. *chinense* with *C. annuum* ranged between 8.9% and 40.0% (Costa et al. 2009), within the genius *C. annuum*, the rate of natural cross-pollination was estimated to be 1.2% overall.(Justino et al., 2018).

During the nineties of the previous century, many hybrid cultivars were introduced for the first time in Southeast Algeria to be cultivated in greenhouses, which were newly and massively installed. In order to satisfy the demands of the market, the growers have shifted their hot pepper production from landraces to the non-native varieties. The replacement of the well adapted local populations to the environment conditions, by hybrid hot pepper varieties led to a drastic genetic erosion which consists of an irreversible loss of genes responsible for the expression of interesting agronomic traits such as adaptability, resistance and/or tolerance to diseases and fruit quality combined to an important loss of knowledge and know-how built up over generations around this crop. Nowadays, in Biskra province, the hot pepper landraces surface is in continuous reduction with 454 ha representing only 30% of total hot pepper area (MADR, 2020).

Currently, the Southeast Algeria is the last rampart of the cultivation of pepper landraces. Over many centuries, farmers have cultivated pepper crops using traditional practices to preserve local populations in various environments, saving and exchanging the seeds, they produced and transferring them from one generation to the next promoting the occurrence of both outcrossing and introgression. This obviously led to phenotypically different populations. Usually, local varieties have varying names that carry the meaning of a specific region or characteristic or use. However, despite the important cultivated area, all pepper landraces in Algeria have the same appellation: Arabian pepper or “Felfel Arbi”. Moreover, a wide range of morphological and chemical variation are observed regarding the fruits characteristics and pungency from one region to another and in some cases within the same region. Unfortunately, no previous reports on *C. annuum* genetic resources from Algeria are available.

In order to effectively utilize and protect plant genetic resources and establish a successful breeding program, it is essential to study genetic diversity and relationships between or within various populations.(Rodriguez et al. 2008) and also to have information on its distribution all over the world (Khadivi-Khub et al., 2014). Furthermore, it is of utmost urgency the preservation of threatened pepper germplasm and development of strategy that emphasize the conservation of hot pepper genetic resources in Algeria. To the best of our knowledge, this is the first study on the genetic diversity of Algerian pepper accessions.

Phenotyping is a quick and widely used tool for identifying and characterizing the germplasm. We used multivariate analysis methods that conveniently enable the recognition of characters primary responsible for phenotypic variation, and provide tools to measure and assess the differences and the similarities intra and inter accessions using multiple quantitative and qualitative characters.

In this context, the present study was planned with the objectives:

1) To prove the presence of phenotypic divergence within Algerian hot pepper landraces by estimating its magnitude;
2) To evaluate the diversity within these accessions using agro-morphological traits and determine their contribution for the genetic variability.
3) To build a database on hot pepper genotypes in Algeria and make it available for future breeding and improvement programs.

MATERIELS AND METHODS

Experimental site

The field experiments were carried out at the Department of agronomical sciences, Biskra University in Algeria. The area has arid climate and the soil is of sandy-loam type.

The seeds of the accessions were sown in nurseries in polystyrene trays containing organic substrate in greenhouses to minimize environmental effects on all the phenotypes. After 50 days, six plants of each accession were transplanted to soil in a greenhouse (Fig. 1), arranged in rows spaced 1m, with 0.50 m between plants. The rows were covered with black plastic mulching type to make weed control and contribute to maintenance of soil moisture. The plants were irrigated by drip irrigation system. The experimental design was a randomized complete block (RCBD) with four replications.

Fig 1. Experiment site.

Phenotyping and plant material

The germplasm studied consisted of 21 accessions of hot pepper collected from six provinces (Biskra: 34°83'01" N 5°76'16" E; El Oued: 33° 22' 16.823" N 6° 50' 52.686" E; Msila: 35° 18' 59.879" N 4° 14' 0.008" E; Tebessa: 35° 23' 60" N 8° 7' 0.001" E; Touggourt: 33° 5' 58.588" N 6° 4' 42.637" E) across the east and south of Algeria. The number of samples varied according to the importance of the pepper production area per province and the availability of the seeds. We labelled each sample with the name of the province then the locality of collection. The seed samples were collected in rural properties from local farmers who saved and transferred these landraces from generation to the next and exchanged among them within the village or beyond. Data depicted in Table 1 showed detail description of the genotypes source and the accession code.

For the morphological characterization, 62 morph-agronomic characters were measured according to the recommendations and scoring categories of the *Capsicum* descriptor guide (IPGRI, 1995), currently Bioversity International. Twelve random plants of each accession were used; totalling 252 plants, 585 corolla, 252 anthers; 252 filaments; 504 leaves; 420 fruits and 252 seed.

For quantitative characters, data were collected on all the four plants in a replicate and the mean values considered. Qualitative descriptors were scored on all 12 plants per genotype in the experiment. Observations were recorded in healthy and mature plants with respect to 38 qualitative and 24 quantitative characters, which entail 8 vegetative (seedling traits were disregarded) and 16 reproductive traits. All presented in Table 2 with their corresponding codes.

Statistical analysis

The quantitative data for vegetative, inflorescence and fruit characters were subjected to descriptive analysis including maximum, minimum, mean values, standard deviation (SD) and coefficient of variation (CV). The formula of leaf and fruit indices were as follows: Leaf index = leaf length/leaf width and fruit index = fruit length/fruit width. An analysis of variance (ANOVA) was performed at a significant level of $p < 0.05$ to assess the level of variability existing among accessions identify discriminants characters. The correlation between all

Table 1: List of the hot pepper accessions collected in Algeria

Codes	Localities	Provinces
BD1	Doucen	Biskra
BD2		
BD3		
BDj	Djemourah	
BMg	El Megsem	
BSO	Sidi Okba	
BZ1	Zeribet El Oued	
BZ2		
EHk	Hassi Khelifa	El Oued
EL1	Lizireg	
EL2		
EL3		
EL4		
EL5		
ETr	Trifaoui	
MAk	Ain AlKhadra	Msila
MEk	El-Khoubana	
MOa	Ouled Ammar	
MOi	Ouled Ichir	
TFe	Ferkane	Tebessa
TGr	Touggourt	Touggourt

variables was calculated using Pearson's Correlation coefficient (r) at $P = 0.05$. Principal Component Analysis (PCA) and Pearson Correlation Matrix (PCM) were used to identifydiscriminants characters and establish relationships between characters. Principal components (PCs) with Eigen value > 1.0 were used as criteria to determine the number of PCs (Kaiser, 1960). Theoretically, the corresponding PC provides more information than any single variable and may be considered a major factor (Lotti et al., 2008). The clustering of accessions into different groups was obtained from a Hierarchical Ascending Classification (HAC) by Ward's method (Ward, 1963).

Qualitative trait data were summarized to calculate the Shannon–Weaver diversity index (H') (Shannon and Weaver, 1948) and provide the distributions and frequencies per class of trait then subjected to multiple correspondence analysis (MCA) in order to identify the pattern of morphological qualitative variation of different genotype groups.

The associations among the accessions were examined by hierarchical clustering, unweighted pair-group method using arithmetic averages (UPGMA) with Euclidean distance method. All analyses were carried out using XLSTAT 2016.02.27 software.

RESULTS

Regarding the quantitative data, the descriptive statistics and correlations analysis revealed a broad phenotypic

Table 2: List of the 24 quantitative and 38 qualitative descriptor traits used in the agro-morphological evaluation

Descriptor categories	Quantitative traits	Codes	Qualitative traits	Codes
Mature plant	Plant height [cm]*	PH	Plant height *	PH
	Plant canopy width [cm]	PCW	Plant growth habit	PGH
	Stem length [cm]	SL	Branching habit	BrH
	Stem diameter [cm]	StD	Tillering	T
	Plant height/Stem length	PH/SL	Leaf density	LD
	Mature leaf length [cm]	LL	Nodal anthocyanin	NA
	Mature leaf width [cm]	LW	Stem colour	StC
	Mature leaf index	LIx	Stem shape	SS
			Stem pubescence	SP
			Leaf colour	LC
			Leaf shape	LS
			Leaf pubescence leaves	LP
Inflorescence Recorded on fully open flowers in the first fresh flowering	Corolla length [mm]*	CL	Flower position	FP
	Anther length [mm]	AL	Corolla shape	CS
	Filament length [mm]	FiL	Corolla colour	CC
			Corolla spot colour	CSC
			Corolla length*	CL
			Filament colour	FiC
			Anther colour	AC
			Stigma exsertion	SE
			Number flower per axil	NF/A
			Calyx pigmentation	CP
			Calxy margin	CM
			Calxy annular constriction	CAC
Fruit Recorded on mature fruits in the first harvest unless specified	Days to fruiting	DyF	Fruit set	FSt
	Fruit bearing period[d]	FBP	fruit colour at intermediate stage	FCi
	Fruit length [cm]	FL	Fruit colour at mature stage	FC
	Fruit width [cm]	FW	Anthocyanin spots	AtS
	Fruit index	FIx	Fruit shape	FS
	Fruit weight [g]	FWg	Fruit shape at pedicel attachment	FSP
	Pedicel length [cm]	PdL	Neck at base of fruit	NBF
	Fruit wall thickness [mm]	FWT	Fruit shape at blossom end	FSB
	Number of locules	NLc	Fruit blossom end appendage	FBEA
	Placenta length [mm]*	PcL	Fruit cross-sectional corrugation	FCr
	Placenta/fruit length	PcL/FL	Fruit surface	FSr
			Placenta length*	PcL
			Ripe fruit persistence: Pedicel with fruit	RFP
			Varietal mixture condition	VMC
Seed	Seed diameter [mm]	SD	Number of seeds per fruit*	NS/F
	Number of seeds per fruit*	NS/F	Seed colour	SC
			Seed surface	SSr
			Seed size	SSz

*: Traits considered as quantitative and ordinal variables for performing PCA and MCA respectively

variation was found for most of the studied parameters in the Algerian *Capsicum annuum* accessions. The mean values of the quantitative traits were calculated and the descriptive statistics including minima, maxima, means, standard deviations and coefficients of variation (CV %) are recorded in Tables 3 and 4 respectively. The range of variation for most characters was large in particular those related to the fruit characteristics such as seed number, weight, width and Fruit wall thickness with 5-110.75, 4.85- 24.98g, 1.18-3.45cm and 1.06-2.18mm respectively. The coefficient of variation for quantitative traits indicates phenotypic characters' degree of dispersion; the larger the coefficient of variation, the greater the dispersion values of the measured traits. According to our results, it varied from 4.65% (seed diameter) to 63.18% (number of seeds per fruit). It is therefore obvious that the coefficient of vegetative traits' variation, except stem length, were relatively backward comparing to the reproductive part where the variation was greater. Within the same accession, no variation was observed for the two parameters: number of days to fruiting and the Fruit bearing period that varied from 68 to 80 and 40 to 57 respectively.

By performing variance analysis using Post-hoc Tukey's tests, it was evidenced significant differences in averages for the majority of the evaluated quantitative traits and the effect of accession was confirmed. The variance was very highly significant ($p < 0.001$) for ten parameters all belong to the reproductive part. While plant canopy width (PCW), Filament length and number of seeds per fruit were not affected by genotypes (Table 4).

Table 3: Mean values of the 21 accessions of Algerian local pepper (*Capsicum annuum* ssp.) with respect to 24 morphological quantitative character

Acce-ssion	PH	PC W	SL	SD	PH/ SL	LL	LW	LIx	CL	AL	FiL	Dy F	FB P	FL	FW	FIx	FWg	Pd L	FW T	NLc	PcL	FL/ PcL	SD	SN/F
BD1	53.67	57.88	23.92	1.48	2.28	8.10	4.78	1.70	11.35	2.63	2.16	80	40	5.89	2.72	2.23	13.92	3.27	1.59	3.75	1.56	3.80	3.62	46.25
BD2	63.33	64.59	26	1.76	2.44	7.62	4.14	1.84	11.12	2.38	2.10	69	57	8.84	3.18	2.80	24.98	2.83	1.92	3.50	1.95	4.57	3.81	5
BD3	54.46	58.33	21.38	1.66	2.59	8.53	5.25	1.62	11.41	2.40	2.10	75	50	6.87	2.73	2.53	14.75	3.48	1.65	3	1.61	4.25	3.85	100
BDj	67.34	58.58	29.42	1.49	2.41	7.53	3.96	1.95	9.40	2.51	1.72	80	40	8.27	1.18	7.17	4.85	3.84	1.07	2	3.28	2.52	3.55	63.75
BMg	58.30	52.63	21.75	1.45	2.85	7.01	4.44	1.65	11.26	2.62	2.37	80	40	8.05	2.67	3.05	14.78	3.72	1.26	2.75	2.15	3.74	3.98	110.75
BSO	54.71	54.34	17.33	1.53	3.16	7.24	4.07	1.79	11.29	2.67	2.44	80	40	7.34	2.51	2.93	13.31	3.55	1.31	3	1.87	3.97	3.63	63.25
BZ1	54.13	53.83	24.04	1.55	2.26	8.63	4.71	1.84	10.27	2.64	2.15	80	40	7.60	2.27	3.43	14.97	3.61	1.45	2.75	2.45	3.16	3.45	76.25
BZ2	45.54	48.96	21	1.42	2.18	8.22	4.09	2.03	10.64	2.37	2.21	69	57	6.27	2.69	2.34	16.04	2.69	1.68	3.25	1.91	3.31	3.66	51.25
EHk	57.79	58.84	21.88	1.24	2.67	8.47	4.61	1.83	10.62	2.21	2.10	80	40	5.43	2.81	1.94	13.61	2.95	1.57	3.25	1.89	2.91	3.61	21.25
EL1	51.75	50.71	17.33	1.36	3.28	6.63	3.46	1.91	10.73	2.05	2.07	69	57	5.87	2.55	2.33	11.48	2.64	1.43	3.25	2.02	2.96	3.43	17
EL2	52.09	54.75	21.67	1.38	2.47	8.55	4.21	2.04	10.55	2.44	2.09	75	50	6.71	3.02	2.22	21.38	2.76	2.18	3.25	2.26	2.98	3.90	10.25
EL3	58.62	57.29	19.31	1.57	3.07	8.79	4.48	1.96	10.71	2.45	1.96	80	40	5.73	2.89	1.99	15.85	3.30	1.69	3.50	1.78	3.23	3.85	64
EL4	50.09	58.59	19.25	1.44	2.62	8.30	4.51	1.84	11.81	2.39	2.29	75	50	6.45	2.90	2.24	16.28	3.24	1.53	3.50	2.14	3.03	3.49	45.25
EL5	54.84	60.42	15.54	1.53	4.51	8.90	4.33	2.07	10.84	2.39	2.25	75	50	6.85	3.08	2.23	18.03	3.30	1.49	3.75	2.14	3.28	3.53	28.75
ETr	45.83	52	15.29	1.41	3.07	8.38	4.35	1.94	10.06	2.21	2.12	80	40	6.19	2.83	2.27	16.29	2.76	1.75	3.25	1.96	3.18	3.49	46.75
MAk	47.29	42.46	20.17	1.35	2.63	7.88	4.16	1.91	12.28	2.53	2.22	69	57	7.10	2.71	2.62	14.38	2.67	1.34	3.50	1.53	4.80	3.91	25.25
MEk	54.92	55.46	20.83	1.38	2.67	7.50	4.54	1.65	11.08	2.37	1.95	80	40	5.83	2.71	2.15	14.65	3.06	1.84	3.25	1.88	3.11	3.60	16.75
MOa	52.42	57.04	14.63	1.49	4.55	7.88	4.53	1.74	11.08	2.32	2.19	80	40	6.12	2.76	2.22	15.05	3.16	1.65	3.75	1.75	3.49	3.84	32
MOi	54.96	58.25	22.46	1.64	2.56	7.82	4.62	1.69	12.57	2.48	2.29	75	50	5.54	3.31	1.68	15.29	3.22	1.53	3.50	1.44	4.10	3.81	54
TFe	47.96	51.92	25.04	1.45	1.95	9.04	4.45	2.04	10.49	2.20	2.13	80	40	5.22	3.45	1.52	15.38	2.92	1.40	4	1.46	3.61	3.80	16
TGr	50.21	56.67	20.21	1.40	2.58	6.50	3.36	1.94	9.93	2.17	1.94	69	57	5.28	1.84	2.90	5.82	2.42	1.06	2.50	1.57	3.36	3.46	96

Table 4: Results of descriptive statistics and Anova analysis for the 24 studied quantitative characters

Variable	Minimum	Maximum	Mean	Coefficient of variation	Standard deviation
PH	45.54	67.34	53.82*	9.78	5.40
PCW	42.46	64.59	55.41	8.25	4.68
SL	14.63	29.42	20.88*	17.20	3.68
SD	1.24	1.76	1.47	7.92	0.12
PH/SL	1.95	4.55	2.80*	23.10	0.66
LL	6.50	9.04	7.98	8.80	0.72
LW	3.36	5.25	4.33*	9.53	0.42
LIx	1.62	2.07	1.86**	7.39	0.14
CL	9.40	12.57	10.93**	6.67	0.75
AL	2.05	2.67	2.40***	6.83	0.17
FiL	1.72	2.44	2.14	7.34	0.16
DyF	69.00	80.00	76.19	5.91	4.61
FBP	40.00	57.00	46.43	15.43	7.34
FL	5.22	8.84	6.54***	15.22	1.02
FW	1.18	3.45	2.70***	17.72	0.49
Fix	1.52	7.17	2.61***	42.65	1.14
FWg	4.85	24.98	14.81***	27.97	4.25
PdL	2.42	3.84	3.11**	12.25	0.39
FWT	1.06	2.18	1.54***	16.91	0.27
NLc	2.00	4.00	3.25***	14.04	0.47
PcL	1.44	3.28	1.93***	20.76	0.41
FL/PcL	2.52	4.80	3.49***	16.26	0.58
SD	3.43	3.98	3.68***	4.65	0.18
SN/F	5.00	110.75	47.13	63.18	30.51

(*), (**) and (***) = significant at 5, 1% and 1‰ probability level respectively

The correlation matrix (Table 5) revealed important correlations almost positive between parameters describing the general vigour of the plant for both vegetative and reproductive characters as height, canopy width, stem length and diameter, lengths of fruit, placenta and pedicel. Leaf width was highly correlated with leaf length that was also correlated to interesting fruits characteristics like width, weight, wall thickness and number of locules. These two latest characters had high positive correlations with both fruit weight and width that was negatively correlated to the placenta length. A strong positive correlation was observed between corolla and filament lengths and fruit width just as between anther and pedicel lengths. The same trend was recorded for fruit, placenta and pedicel lengths. Correlation matrix also revealed a high negative significant intercorrelation between placenta and corolla lengths and interestingly between days to fruiting and fruit bearing period.

Using Kaiser's criterion (Kaiser, 1960) we considered the first five significant principal components with Eigen values distinctly above 1 explaining 76.877% of the total variation (Table 6). Nine traits were associated with 1st component: fruit index; placenta length and plant height (positive loadings) and corolla length; filament length; fruit width and weight; fruit wall thickness and number of locules (negative loadings). PC2 was correlated positively with pedicel length; leaf width; anther length; stem diameter; seed diameter and fruit length and negatively with leaf index. Two high positive loadings of fruit length/placenta length ratio and fruit bearing period and two high negative loadings of leaf length and days to fruiting determined the 3rd PC. The 4th PC was related to number of seed per fruit while the 5th opposed plant height/stem length ratio and stem length.

The PCs results showed a distinct separation of the accessions based on regions suggesting a high morphological variation among the accessions even those cultivated in the same province for the considered quantitative parameters. When identified by provinces or localities, accessions from the same province were not grouped necessarily with each other.

The accessions BDj, BZ1 were characterized by the highest plant and placenta length when MOi had important fruit traits like width, fruit wall thickness and number of locules that determine the fruit weight. The following accessions: BD1, BD3, BMg shared traits related to the high values of diameter of stem and seed; anther; filament and pedicel lengths when BZ2 EL1, TGr were identified by the highest leaf index.

MAk accession was the earliest with the lowest number of days to fruiting and accordingly the longest fruit-bearing period on the contrary of ETr, EHk and EL3 accessions

Table 5: Pearson's correlation matrix between the different quantitative characters (Abbreviations as in Table 2)

Var	PH	PCW	SL	SD	PH/SL	LL	LW	LIx	CL	AL	FiL	DyF	FBp	FL	FW	FIx	FWg	PdL	FWT	NLc	PcL	FL/PcL	SD
PCW	**0.65***																						
SL	**0.52**	0.20																					
SD	0.42	**0.53**	0.22																				
PH/SL	0.02	0.16	**-0.76***	0.03																			
LL	-0.16	0.10	0.03	0.12	-0.04																		
LW	0.07	0.24	0.09	0.31	-0.06	**0.64***																	
LIx	-0.24	-0.21	-0.04	-0.26	0.01	0.30	**-0.53**																
CL	-0.16	-0.09	-0.18	0.23	0.06	0.00	0.38	**-0.51**															
AL	0.32	0.01	0.29	0.37	-0.15	0.09	0.39	-0.35	0.32														
FiL	-0.37	-0.20	-0.41	0.11	0.22	0.06	0.23	-0.24	**0.65***	0.34													
DyF	0.27	0.19	0.05	-0.04	0.10	0.34	**0.54**	-0.29	-0.19	0.33	-0.01												
FBP	-0.27	-0.14	-0.07	0.07	-0.08	-0.28	**-0.48**	0.28	0.24	-0.31	0.05	**-0.99***											
FL	**0.54**	0.14	0.34	**0.45**	-0.03	-0.14	-0.01	-0.09	-0.04	**0.54**	0.08	-0.06	0.05										
FW	-0.33	0.05	-0.26	0.18	0.09	**0.49**	0.41	-0.02	**0.55***	-0.13	**0.54**	-0.03	0.08	-0.28									
FIx	**0.58***	0.10	**0.50**	0.09	-0.14	-0.30	-0.27	0.07	**-0.48**	0.31	**-0.49**	0.11	-0.13	**0.61***	**-0.85***								
FWg	-0.08	0.18	-0.11	0.36	0.06	**0.47**	0.35	0.05	0.36	0.09	0.42	-0.11	0.15	0.22	**0.79***	**-0.53**							
PdL	**0.59***	0.32	0.26	0.41	0.09	0.13	**0.49**	-0.43	0.04	**0.69***	0.11	**0.64***	**-0.61***	**0.48**	-0.26	**0.48**	-0.15						
FWT	-0.11	0.19	-0.13	0.13	0.00	**0.44**	0.36	0.00	0.15	-0.08	0.03	-0.01	0.05	-0.06	**0.59***	**-0.48**	**0.80***	-0.28					
NLc	-0.40	-0.01	-0.35	0.06	0.24	**0.49**	0.32	0.08	**0.50**	-0.18	0.42	-0.02	0.05	-0.41	**0.87***	**-0.79***	**0.61***	-0.32	**0.48**				
PcL	**0.53**	0.17	0.32	-0.03	0.01	-0.05	-0.19	0.24	**-0.56***	0.21	-0.38	0.21	-0.21	**0.59***	**-0.61***	**0.81***	-0.20	**0.47**	-0.14	**-0.63***			
FL/PcL	-0.09	-0.12	0.04	**0.48**	-0.09	-0.07	0.21	-0.36	**0.68***	0.31	**0.47**	-0.33	0.32	0.25	0.39	-0.28	0.35	-0.07	0.02	0.32	**-0.60***		
SD	0.11	-0.12	0.13	0.25	-0.05	0.16	0.34	-0.22	**0.46**	0.31	0.25	0.03	-0.01	0.17	**0.44**	-0.22	0.41	0.09	0.28	0.28	-0.33	**0.57***	
SN/F	0.11	0.00	0.06	0.22	-0.10	-0.23	0.13	-0.36	-0.08	0.37	0.07	0.16	-0.15	0.16	**-0.46**	0.31	**-0.47**	**0.49**	**-0.52**	**-0.60***	0.07	0.05	0.01

Correlation is significant at 0.01 probability level that had a long leaves. These two landrace accessions from different provinces BD2, EL2 were grouped together and opposed BSO with high number of seed per fruit. Similarly, EL5 and MOa that recorded the lowest number of seed per fruit were distinguished from TFe possessing the longest stem.

For the descriptive statistics and Shannon-Weaver diversity index analysis of morphological qualitative traits, the frequency distributions showed a wide range of variation. In total, eight common traits were recorded including: stem colour (green); corolla colour (white); corolla length (<15mm); corolla spot colour (white); filament colour (white); anthocyanin spots or stripes (absent); fruit colour at intermediate stage (green) and neck at baseof fruit (absent). The characters: one flower per axil; corolla shape, calyx pigmentation were the most predominant (frequency: 95.24). In all traits, the Shannon–Weaver diversity index (H') was higher than 0.50. Moreover, the following traits recorded the highest H' values: fruit shape at blossom end (1.23); seed size (1.1); anther colour (1.09); both stigma exsertion and nodal anthocyanin (1.08); tillering and seed number per fruit (1.05) and branching habit (1.01). The detailed qualitative trait data for various landrace accessions are presented in Table 6.

Table 6: Eigen vectors, proportion and cumulative percentage of variation explained by the first five principal components (PCs) for 24 quantitative traits of 21 Algerian hot pepper accessions

PCs	F1	F2	F3	F4	F5
Eigen value	6.475	4.693	2.984	2.533	1.765
Variance (%)	26.979	19.555	12.435	10.553	7.355
Cumulative (%)	26.979	46.534	58.969	69.522	76.877
Parameters	**Factor loadings (correlation coefficients)**				
PH	**0.568**	0.508	-0.030	0.368	0.209
PCW	0.151	0.398	-0.261	0.366	0.376
SL	0.447	0.293	0.112	0.458	**-0.622**
StD	-0.040	**0.634**	0.251	0.362	0.242
PH/SL	-0.151	-0.033	-0.185	-0.237	**0.873**
LL	-0.365	0.291	**-0.613**	0.182	-0.246
LW	-0.293	**0.752**	-0.329	-0.163	-0.227
LIx	0.021	**-0.594**	-0.249	0.406	-0.014
CL	**-0.624**	0.395	0.454	-0.188	0.028
AL	0.201	**0.748**	0.232	-0.107	-0.098
FiL	**-0.551**	0.310	0.285	-0.354	0.224
DyF	0.229	0.515	**-0.661**	-0.410	-0.081
FBP	-0.262	-0.470	**0.638**	0.419	0.103
FL	0.406	**0.475**	0.351	0.431	0.234
FW	**-0.914**	0.208	-0.158	0.130	-0.011
FIx	**0.921**	0.093	0.129	0.185	0.019
FWg	**-0.685**	0.341	-0.113	0.516	0.128
PdL	0.481	**0.782**	-0.122	-0.218	0.128
FWT	**-0.563**	0.151	-0.363	0.476	-0.001
NLc	**-0.884**	0.056	-0.242	0.044	0.053
PcL	**0.774**	0.064	-0.239	0.320	0.185
FL/PcL	-0.481	0.382	**0.682**	0.034	-0.082
SD	-0.385	**0.478**	0.245	0.105	-0.220
SN/F	0.454	0.278	0.330	**-0.482**	-0.050

The predominant characters above mentioned were disregarded when performing the multiple correspondence analysis (MCA) since they were not polymorphic. The first three factorial dimensions explained 58.68% of the variation among the 21 hot pepper accessions for 34 qualitative traits (Fig. 2). In total, 20 components were required to account for 100% of the observed variation. The first factorial dimension explained the largest variance percentage (42.5%) and 11 descriptor traits, given hereinafter in descending order of contribution values, were mostly associated with this dimension: highest plant (PH-4: 66-85 cm); erect growth habit (PGH-7); erect flower position (FP-7); rotate corolla (CS-1); many flower per axil (NF/A-4); elongated fruit (FS-1) that shape at pedicel attachment was obtuse (FSP-2) and pointed at blossom end (FSB-1); dentate calyx margin (CM-7); intermediate fruit set (FSt-5); serious varietal mixture condition (VMC-7). This description distinguished the BDj accession from all the others. The categories of the variables that contributed most to dimension 2, which accounted for 9.2% of the total variation were: light green leaf colour (LC-2); sunken and pointed fruit at blossom end (FSB-4); high density of leaf (LD-7) and branching habit (BrH-7); rough seed surface (SSr-2); entire calyx margin (CM-3)and white anther colour (AC-6). The position of these variables was indicative of a positive association between them and of a negative one

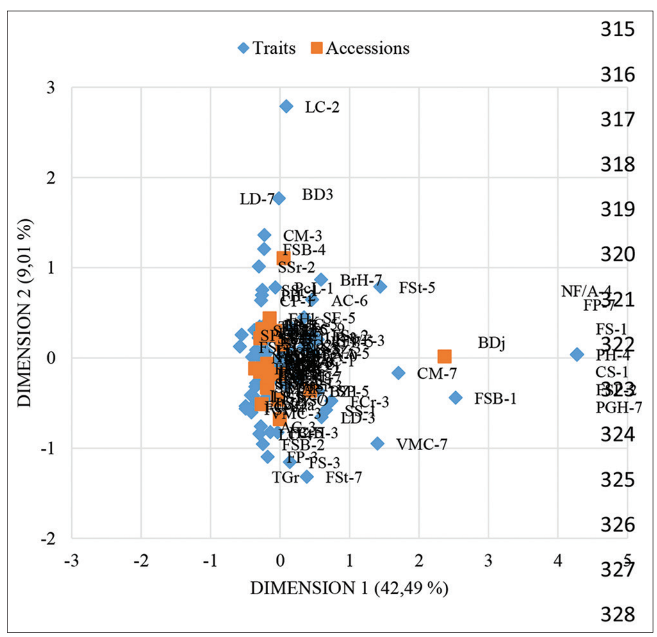

Fig 2. Distribution of the assessed accessions and the modalities of the main traits contributing to the dimensions 1 and 2, observed from the multiple correspondence analyses (MCA).

with the following traits: pendant flower position (FP-3); pale blue anther (AC-3); triangular fruit shape (FS-3); high fruit set (FSt-7); blunt fruit at blossom end (FSB-2) and sparse leaves (LD-3). The accessions representing broadly these two groups of traits were BD3 and TGr respectively.

The third dimension, which explained 7.17% of the total variation, was determined by two groups of variables; the first one included: intermediate ripe fruit persistence (pedicel with fruit) (RFP-5)cordate fruit shape at pedicel attachment (FSP-4); smallest placenta length ratio (PcL-1); lanceolate leaf (LS-3); sparse branching habit (BrH-3); green nodal anthocyanin (NA-1); brown seed (SC-2); cylindrical stem (SS-1). The second group comprised dark green leaf (LC-4); pale orange fruit (FC-5); slight ripe fruit persistence (pedicel with fruit) (RFP-3); purple nodal anthocyanin (NA-5); inserted Stigma exsertion (SE-3); dense tillering (T-7). MAk accessions was the one that most closely corresponds to the 1st group when BMg to the 2nd.

Unsupervised agglomerative hierarchical cluster analysis was used in order to divide the available data up into groups of increasing dissimilarity. The Euclidean distance was used as a metric to measure the genetic dissimilarity of the 21 pepper accessions, based on the combined quantitative and qualitative data, and the Ward's method was used for the agglomeration. The Dendrogram of Fig. 3 pointed out that, most of accessions were different from each other and their distribution across the clusters showed no absolute separation of the accessions by locality subgroups. Thus, dissimilarity analysis produced two major clusters (at 1.96 % dissimilarity coefficient), the Cluster I consisted of a single genotype (BDj) which presented the highest values of plant length; canopy width; stem length; fruit length and index; placenta length and the lowest fruit width; weight; number of locules with an erect habit of the plant; dense branching and tillering; purple nodal anthocyanin; many erect flowers in bunches but each in individual axil; rotate corolla; elongate fruit set and obtuse fruit at pedicel attachment. The other cluster was further sub-divided into three sub-clusters (Clusters II, III and IV), when partitioned at a dissimilarity coefficient of 0.78% for ease of discussion. Cluster II was the largest and contained 11 accessions, with EL4 and MOi being the most similar (at 0.22% dissimilarity coefficient) despite the fact that they don't belong to the same province. Many accessions from the same locality were grouped into this cluster such BD1, BD2 and BD3 or EL2, EL3, EL4 and EL5. This group, exhibited the highest leaf length and width; fruit width and weight; number of locules and an intermediate leaf density and few seed number per fruit. Each of the clusters III and IV had 3 accessions of which BMg and BSO were the closest. The accessions belonging to cluster III had high length filament; important seed number per fruit and sparse branching habit when those to cluster IV, which was the most heterogeneous with EL1, MAk and TGr accessions collected from different provinces, had the lowest values of plant length; canopy width; stem length; days to fruiting and the longest fruit bearing period with blunt fruit shape at blossom end.

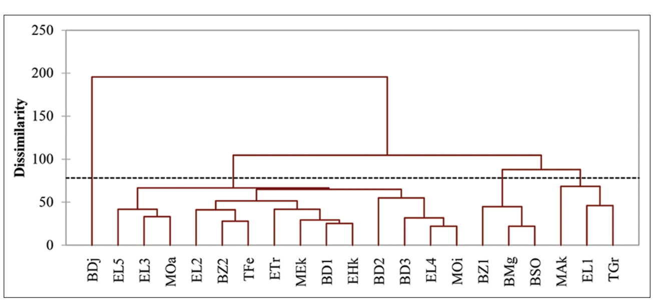

Fig 3. Dendrogram of the hierarchical cluster analysis based on the combined data: quantitative and qualitative traits.

DISCUSSION

Phenotyping is essential to allow understanding and utilizing crop diversity. A sampling comprising twenty-one accessions selected locally over a long period of time by farmers on the basis of relevant and distinguishable agronomical characteristics and mostly collected at different regions in Algeria was assessed with sixty two agro-morphological descriptors. These landraces are still grown today because of their good quality and wide acceptance in the national market. Moreover, they are undoubtedly a precious source of untapped genetic variability that could be easily used in pepper improvement programs. The main goal of this accurate study was to assess genetic diversity of Algerian hot pepper (*C. annuum*) accessions and to provide basic and fundamental knowledge on the spectrum of variation revealed by several agro-morphological plant and fruit traits.

Significant variations in many morphological characters were strikingly demonstrated indicating that genotypes analyzed were different. Compared to others findings on hot pepper (Bharath et al., 2013 and 2014; Nsabiyerao et al., 2013; Virga et al. 2020; Padilha et al. 2016; Orobiyi et al. 2018; Gurung, et al., 2020; Bozokalfa et al., 2011; Shango et al., 2021; Waongo et al., 2021) or other species (Bedjaoui, 2019, Bedjaoui and Benbouza, 2020; Ganopoulos et al. 2015; Ghosh et al., 2013; Sun et al., 2019), the obtained results of both descriptive and multivariate analyses pointed out the presence of distinguished landraces in the set of evaluated genotypes of hot pepper in Algeria, which corroborate the findings of various authors.

The phenotypic characterization of the studied chili peppers accessions pointed out a significant intra and inter-

Table 7: Description, distribution and frequency of qualitative traits and their derived diversity index (H') in pepper accessions of Algeria

Trait	Descriptors	Ac/T	Freq	H'	Trait	Descriptors	Ac/T	Freq	H'
PH	2 25-45 cm	2	9.52	0.50	**CM**	3 Entire	3	14.29	0.8
	3 46-65 cm	18	85.71			**5 Intermediate**	15	71.43	
	4 66-85 cm	1	4.76			7 Dentate	3	14.29	
PGH	3 Prostrate	7	33.33	0.81	**CAC**	0 Absent	6	28.57	0.6
	5 Intermediate	13	61.90			**1 Present**	15	71.43	
	7 Erect	1	4.76		**FSt**	**3 Low**	16	76.19	0.71
BrH	3 Sparse	4	19.05	1.01		5 Intermediate	3	14.29	
	5 Intermediate	11	52.38			7 High	2	9.52	
	7 Dense	6	28.57		**FC**	5 Pale orange	3	14.29	0.86
T	3 Sparse	5	23.81	1.05		8 Red	4	19.05	
	5 Intermediate	6	28.57			**9 Dark red**	14	66.67	
	7 Dense	10	47.62		**FS**	1 Elongate	1	4.76	0.59
LD	3 Sparse	7	33.33	0.91		3 Triangular	3	14.29	
	5 Intermediate	12	57.14			**5 Blocky**	17	80.95	
	7 Dense	2	9.52		**FSP**	2 Obtuse	1	4.76	0.50
NA	1 Green	6	28.57	1.08		**3 Truncate**	18	85.71	
	3 Light purple	9	42.86			4 Cordate	2	9.52	
	5 Purple	6	28.57		**FSB**	1 Pointed	2	9.52	1.23
SS	1 Cylindrical	6	28.57	0.60		2 Blunt	4	19.05	
	2 Angled	15	71.43			**3 Sunken**	10	47.62	
SP	**3 Sparse**	12	57.14	0.91		4 Sunken and pointed	5	23.81	
	5 Intermediate	7	33.33		**FBEA**	**0 Absent**	19	90.48	0.31
	7 Dense	2	9.52			1 Present	2	9.52	
LC	2 Light green	1	4.76	0.73	**FCr**	3 Slightly corrugated	6	28.57	0.96
	3 Green	15	71.43			5 Intermediate	3	14.29	
	4 Dark green	5	23.81			**7 Corrugated**	12	57.14	
LS	1 Deltoid	2	9.52	0.62	**FSr**	**1 Smooth**	11	52.38	0.93
	2 Ovate	17	80.95			2 Semi wrinkled	8	38.10	
	3 Lanceolate	2	9.52			3 Wrinkled	2	9.52	
LP	**3 Sparse**	10	47.62	1	**RFP**	**3 Slight**	15	71.43	0.6
	5 Intermediate	8	38.10			5 Intermediate	6	28.57	
	7 Dense	3	14.29		**PcL**	1<1/4 fruit length	3	14.29	0.41
FP	3 Pendant	5	23.81	0.73		**2 1/4-1/2 fruit length**	18	85.71	
	5 Intermediate	15	71.43		**VMC**	3 Slight	4	19.05	0.86
	7 Erect	1	4.76			**5 Medium**	14	66.67	
CS	1 Rotate	1	4.76	0.19		7 Serious	3	14.29	
	2 Campanulate	20	95.24		**SC**	**1 Straw**	16	76.19	0.55
AC	2 Yellow	6	28.57	1.09		2 Brown	5	23.81	
	3 Pale blue	7	33.33		**SSr**	1 Smooth	1	4,76	0.67
	6 White	8	38.10			2 Rough	4	19,05	
SE	**3 Inserted**	8	38.10	1.08		**1 Smooth**	16	76,19	
	5 Same level	8	38.10		**SSz**	3 Small	7	33.33	1.1
	7 Exserted	5	23.81			**5 Intermediate**	7	33.33	
NF/A	**1 One**	20	95.24	0.19		7 Large	7	33.33	
	4 Many	1	4.76		**SN/F**	1<20	4	19.05	1.05
CP	**0 Absent**	20	95.24	0.19		**2 20-50**	9	42.86	
	1 Present	1	4.76			3>50	8	38.10	

Ac/T: accessions per trait; Freq : frequency; H ′= Shannon–Weaver diversity index

accession variability in terms of qualitative and quantitative descriptors. The high significant differences evidenced by variance analysis using Post-hoc Tukey's tests and coefficients of variation and the variation of the number of modalities, frequencies and Shannon–Weaver diversity index (H') values for the qualitative and quantitative descriptors respectively show the heterogeneity of the investigated accessions.

Differences in growth and yield characters have been reported among pepper genotypes elsewhere (Adetula and Olakojo 2006; Bharath et al; 2013; Zanklan et al., 2018; Shango et al., 2021). Regarding our results, traits describing the plant and fruits showed various and interesting associations. General vigour of plant as height, canopy width and stem dimensions may be good criteria of selection being highly correlated to the lengths of fruit, pedicel and placenta. Similar data were found by Do Rêgo et al. (2011) and Waongo et al. (2021). Accordingly, the strong correlation between leaf dimensions and the most interesting yield characteristics as fruit width, weight, wall thickness and number of locules could be used as indicators on the performance of accessions since leaf area is closely related to photosynthesis activity. This result corroborates the findings of Orobiyi et al. (2018) and Waongo et al. (2021) who highlighted the presence of important correlation between yield parameters and variables forming the vegetative part of the plant. As well, the positive correlation between fruit weight and fruit wall thickness is a valuable selection criterion for varieties suitable for fresh market sale. It should be noted that during postharvest handling, fruits with thicker wall are more resistant to wounding (Lannes et al., 2007; Rêgo et al., 2011). On the other hand, fruit width selection may result in higher gains in fruit weight and consequently in yield. (Rêgo et al., 2011; Pinto et al., 1999). Our results also showed that the earliest accessions had the shortest fruit bearing period and could be recognized by long pedicel. Similar findings were observed on hot pepper populations in Tunisia (Lahbib et al., 2013), in India (Yatung et al., 2014) and in Northern Benin (Orobiyi et al., 2018).

Previous studies (Lahbib et al., 2013, Wang Ming, 1988) have shown highly significant correlations between placenta weight and fruit wall thickness. In our study, the contrary was observed because the fruit width and index expressed a strong negative correlation with fruit and placenta lengths. Accessions showing higher placenta weight may be accumulate higher level of capsaicinoids responsible for the pungent taste as they are synthethized in placental tissue (Suzuki and Iwai, 1984). Interestingly, these findings correspond to knowledge of Algerian local populations who recognize the hottest pepper by their elongated form and thin wall.

In order to identify the most discriminant variables in the set of data presented herein, we used PCA to suggesting that assessments in the future can focus solely on fewer traits with less information loss allowing characterization of accessions actually resulted in time and labor savings (Rêgo et al., 2003; Bharath et al., 2013; Ganopoulos et al., 2015). PCA result further confirmed the presence of variations observed in the ANOVA data. Nevertheless, the most relevant description of the phenotypic diversity of the studied landraces were determined by this method, which provide information showing the presence of high levels of dissimilarity between different studied landraces even those belonging to the same localities. In agreement with findings of Belay et al. (2019) and Rivera et al. (2016), most yield and fruit characteristics contributed to PC1 confirming that the ongoing selection and domestication of pepper have led to a significant rise in the observed fruits variation (Paran et al., 2007).

On the other hand, the distribution of studied accessions in different groups assess the presence of variation between landraces belonging to same province and also to the same locality as the case of the accessions collected from Doucen (BD1 and BD2) and Zribet El Oued (BZ1 and BZ2) in Biskra province. Nevertheless, the following accessions ETr, EHk and EL3 from El Oued province were grouped together. The MOi accession was the most isolated from the rest and consequently the most considerably diverse. As regard the weight of its fruit, this accession might be considered as a good candidate for pepper improvement. The BDj and BZ1landraces being tall with long placenta might conceivably serve as a potential sources of genes responsible for pungency and height. Several accessions had varying fruiting and harvest periods evidencing variation for their cycle of reproduction. The earliness exhibited by MAk accession is a valuable characteristic pointed out by our results. This attribute is very valuable in monitoring the seed development time which has a direct impact on some plant characteristics like seed physiological quality and seed viability (Martins et al., 2010; Mengarda and Lopes, 2012).

As regard the variation in the qualitative traits, eight from the 38 studied did not vary. Ripe fruit persistence was slight and intermediate depending on the accession. In general, pepper selections programs are designed to intermediate persistence of peduncle and fruit in order to reduce difficulty at harvesting. (Martins et al., 2010).

Our findings are, for almost, in accordance with those obtained by Nsabiyerao et al. (2013) works on morphological characterization of thirty-seven Hot Pepper (*Capsicum annuum* L.) Collections in Uganda and also, in accordance with those stated by Orobiyi et al. (2018) who, investigated the agro-morphological diversity of Benin chili pepper landraces. A certain degree of variation was pointed out concerning several qualitative characters , and this could be used to discriminate among *Capsicum annuum* genotypes. These features comprised fruit size, shape and surface, placenta length ratio, nodal anthocyanin, stem pubescence type, anther colour, flower position, corolla shape, stigma exsertion, nodal anthocyanin, branching habit, leaf colour, varietal mixture condition, seed size and colour. Such distribution pattern of genotypes and qualitative traits on the MCA dimensions showed the prevalence of genetic variability among hot pepper genotypes. In plants, most of time the taxonomic and botanical distinctions among species are generally made on the base of floral traits. As assessed by Sudré et al. (2010) and Bharath et al. (2013), the white corolla and the absence of fruit neck at pedicel attachment could be used to differentiate *Capsicum annuum* L. from the other species. Regarding our findings, these characters were monomorphic allowing us to conclude that all studied genotypes belong to *Capsicum annuum* L. However, the anthocyanin spots or stripes were absent among the landraces we investigated in contrast to what has been reported by Nsabiyerao et al. (2013) who observed them on 11 % of the genotypes of the same species. We should note that plant response to both biotic and abiotic stresses is determined by the presence of anthocyanin in leaves, being implicated in various defence mechanisms (Gould, 2005).

Hierarchical cluster analysis allowed a more effective exploration of our data. Notably in the current study, dissimilarity analysis based on both quantitative and qualitative data produced four main clusters with no obvious separation of accessions according to localities or provinces, because the majority of the clusters included accessions from all regions. Nevertheless, some neighboring accessions were closely related; but, no pairs or groups from the same locality or province were noticed to be identical revealing a high level of variability within and between genotypes. Our results are close to those found by Bharath et al. (2013); Bozokalfa and Esiyok (2011); Nsabiyerao et al. (2013) and Gurung, et al. (2020).

The observed heterogeneity of the studied accessions is proportional to the extent of the explored area and could primary be explained by the different agro-climatic conditions in Algeria. In this regard, Shango et al. (2021) claimed that the variation in plant characters among pepper populations may be attributed to a variety of considerations including genetic variations, edaphic characteristics and environment impact. Moreover, rainfall distribution, diseases incidence and spike shedding could also be at the source of variation in pepper varieties development and performance (Bhagavantagoudra et al., 2008; Preethy et al., 2018)

On the other hand, genetic diversity level within and between crops is determined by their reproductive behavior (Geleta et al., 2005). Furthermore, the reproduction mode of peppers is predominantly allogamous resulting in genetic mixing and species diversification (Segnou et al., 2012; Bozokalfa and Esiyok, 2011). In addition, among the factors enabling the justification of the observed variation we can cite the diverse and several pepper genotypes introduced to Algeria from many countries leading to gene flow between cultivated populations across many localities associated to some socio-cultural considerations on the chili pepper characteristics or economic value would have guided farmers in their selection process. This latest being essentially based on traditional local know-how like the seed saving methods and cultivating in adjacent plots followed by pepper growers in Algeria.

CONCLUSION

This study has highlighted the existence of great variability in the landraces of hot peppers in Algeria and, interestingly, revealed that the knowledge of local population were in perfect adequacy with our findings. The significant differences, observed by most of the studied traits revealed that they allow discrimination of the genotypes. Since the phenotypic characters are directly influenced by the environmental factors, the comparison between qualitative and quantitative data indicated the presence of quantitatively identical accessions that are qualitatively different and vice versa. It is therefore crucial to clarify the links between these landraces by making reference to other characterizations as biochemical and molecular characterizations in order to know more the number of landraces that really exists. In addition, this study provides justification for starting conservation process and more in-depth evaluation of the hot pepper landraces. It is expected to contribute to future decisions concerning the establishment of conservation and improvement programs of genetic resources of peppers that must be considered as a reservoir of genes with the potential to solve agricultural problems in Algeria.

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Authors' contributions

All authors carried out prospections to collect the landrace seeds. Hanane Bedjaoui performed statistical analyses and carried out the first draft of the paper. Nadia Boulelouah elaborated the experiment design and contributed to the data analysis. Mohamed Seghir Mehaoua supervised the interpretation of the results Sarah Badache and Soumia Boutiba carried out the fieldwork with the first: Hanane Bedjaoui and the 3rd author: Mohamed Seghir

Mehaoua and collected data. Salima Baississe and Lyes Reguieg participated in the development of the research, and in the revision of the article.

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