academicresearchJournals

Vol. 6(9), pp. 531-538, December 2018
DOI: 10.14662/ARJASR2018.076

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

Academic Research Journal of Agricultural Science and Research

Full Length Research

Variation in Pheno-Qualitative Characters of Ethiopian Coriander (*Coriandrumsativum* L.) Accessions

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Accepted 20 December 2018

Coriander (*Coriandrumsativum* L.) is an annual spice herb that belongs to the family Umbelliferae. Even though coriander has got diverse uses and Ethiopia is a center of primary diversity for the crop, the current knowledge about its biology and agronomy are neither complete nor conclusive under Ethiopian conditions. To contribute in addressing the existing knowledge and information gaps this activity was intended to evaluate the phenotypic qualitative traits of Ethiopian coriander accessions. Test trial was conducted at Kokate and Wondo Genet, Southern Ethiopia. Forty nine coriander accessions were tested using 7 x 7 simple lattice designs. Data for 7 qualitative traits were collected. SAS package was used for data analysis. Clustering of accessions was performed following the Mahalanobis's D^2 distance procedure. Qualitative traits variation was observed on habit of the basal leaves, leaf and flower color indicating their diagnostic value in coriander characterization and these qualitative traits can be considered as important morphological markers in coriander breeding programs for improving the yield and quality traits of coriander. As an instance, coriander plants with deep green flat basal leaves had high seed yield and low oil contents; light green erect basal leaves had low seed yield and high oil content; and inclined basal leaves had intermediate values in seed yield and oil content. The study brought out the presence of substantial variability in phenotypic qualitative traits among accessions suggesting clue for further research and development activities and these traits can be used for screening of coriander accessions at the earlier stage of development.

Key Words: Coriander, Ethiopia, Phenotype, Qualitative Characters, Variability

Cite this article as: Kassahun, B.M. (2018). Variation in Pheno-Qualitative Characters of Ethiopian Coriander (*Coriandrumsativum* L.)Accessions. Acad. Res. J. Agri. Sci. Res. 6(9): 531-538

INTRODUCTION

Coriander (*Coriandrumsativum* L.) is an annual spice herb that belongs to the family Umbelliferae (Diederichsen, 1996; Parthasarathy *et al*., 2008). The origin of coriander is uncertain, the area suggested by most authors being the Near East (Diederichsen, 1996). Some authors Vavilov (1992) for example suggested a much wider origin for coriander which includes central Asia, the Near East and Abyssinia. It is native to Mediterranean and Western Asian regions (Maroufi *et al*., 2010). Ethiopia has long been known as a centre of origin and diversity for several plants. From several plant species, coriander (*Coriandrumsativum* L.) is the one in which Ethiopia is known as a centre of primary diversity (Jansen, 1981).

In Ethiopia, it is known by different local names i.e. dembilal (Amharic); debo, shucar (Oromiffa); tsagha, zagda (Tigrignya); and tibichota (Konsonya) (Goetsch *et al*., 1984; Jansen, 1981), indicating its economic significance in diversified societies of the country. The mature fruits, commonly named as seeds and the fresh green herb are the economically important parts of the coriander plant. These may be consumed directly or indirectly used for other purposes after processing; however, the two products are different in odor and flavor (Diederichsen, 1996; Fogg, 1978; Shweel-Cooper, 1973; Williams *et al*., 1991).

Coriander seed is found in every market of the country at a high price. In southern Ethiopia, leaves and the immature fruits are used as an ingredient for the preparation of "data". The seed as a spice is used in most parts of the country. Hence, coriander is widely used in the diversified societies of the country.

So far there aredifferent scientific studies conducted on coriander's botanical (Diederichsen, 1996; Diedrichsen and Hammer, 2003) and chemical characteristics (Mandal and Mandal, 2015; Kurkcuoglu*et al*., 2003; Lawrence, 1997; Pino *et al*., 1996); but there is only a small amount of work concerning agronomic practices and evaluation activities (Beemnet and Getinet; 2010; Beemnet*et al*., 2013; Awas*et al*., 2015;), with the exceptions of fertilization, which has been carefully studied under many environmental conditions (Ghosh *et al*., 1985; Hornok, 1983, 1986; Oliveira *et al*., 2003; Rahman *et al*., 1990), irrigation (Khashmelmous, 1984), and disease control (Dennis and Wilson, 1997; Singh *et al*., 2003). The effect of sowing time under irrigation has been studied in Argentina by Luayza*et al*. (1996), who stated that, under non-stressed environmental conditions, autumn–winter sowing should be optimal for achieving the highest yields. A field trial performed in Argentina (Fuente *et al*., 2003) suggests the possibility to introduce coriander for essential oil production as a means for the exploitation of poor soil environments.

In Ethiopia, the Ethiopian Institute of Biodiversity Conservation (IBC)has made an extensive collection of coriander of these, accessions reach for long term are maintained at Wondo Genet; however, there is little effort to characterize and evaluate the accessions. Consequently our knowledge of the nature and extent of coriander variation that exists in Ethiopia germplasm is limited. This lack of information is a major hindrance to exploit the wealth of coriander diversity in Ethiopia. Evaluation activities on agronomic quantitative characteristics (Beemnet and Getinet; 2010; Beemnet *et al*., 2013; Awas *et al*., 2015).This clearly indicates the current knowledge about its characteristics on phenotypic qualitative characters which are important for conservation, characterization, selection and improvement are neither complete nor conclusive under Ethiopian condition. Therefore, the Ethiopian coriander accessions need to be properly characterized and evaluated for their phenotypic qualitative characters, and their attributes have to be known to the breeders either for direct use or for other improvement programs. Furthermore, the value of the conserved germplasm will depend greatly upon the information available on each accession. Therefore, to contribute for exploiting the wealth of coriander diversity and contribute in addressing the existing knowledge and information gaps this activity was intended with the objective of evaluating the phenotypic qualitative traits of Ethiopian coriander accessions for further improvement and development program.

MATERIALS AND METHODS

Description of the study sites: The experiment was conducted inwolocations at Kokate site of Delbo watershed Kokate site and Wondo Genet Agricultural Research Center trial site, Southern Ethiopia. Delbo watershed is found in Wolayita Zone of SNNPRS, is located 16 km away from Sodo town of Latitude of 6°53' N and Longitude 37°52' E. The altitude of Delbo watershed ranges from 1990 to 2061m and Kokate site is 2100 m.a.s.l (GPS reading). According to Sodo Zuria Woreda Rular Development Office (2006), Kokate site has a humid climate with an average annual temperature of 18°C; monthly mean temperatures range from 17°C in July to 22°C in February; and average annual precipitation of about 1300 mm and well distributed throughout the growth period with 83% of the rainfall falling between April and October every year. The soil of the site is sandy loam having 0.11% total N, 2.31ppm available Phosphorous and 3.84% organic matter with a pH of 4.81 (Elzabeth, 2007).Whereas, Wondo Genet Agricultural Research Center testing site is located at 7°19' N and 38° 38' E latitude and longitude, respectively. The altitude of the site is 1780 m.a.s.l. This area receives mean annual rainfall of 1000 mm with maximum and minimum temperature of 10 and 30°C, respectively (Woobeshet, 2001). The soil textural class of the experimental area is sandy clay loam having with average pH of 7.2 (Ethiopian National Soil Laboratory, 2004).

Treatments and Design: The experiment included 49 accessions. A 7 x 7 Simple Lattice Design was employed following the procedures of Gomez and Gomez (1984). Each replication contained 49 plots divided in to 7 incomplete blocks. Each incomplete block contains 7 plots with an area of 3.6m^2 (1.8 m length x 2m width). The respective spacing between rows and plants were 40cm and 30cm. There were 5 rows per plots having 6 plants and a total of 30 plants were maintained per plot. Spacing of 1m and 2 m was kept between plots and replications, respectively.

Crop Management: Coriander accessions collected from different parts of the country by the Institute of Biodiversity Conservation (IBC) and maintained at the

Table 1. Qualitative traits used for characterizing coriander accessions

Part	Traits	Description
Vegetative	Blade shape of the longest basal leaf	1 =Entire or slightly insected 2=Deeply incised with 3 lobes 3=once pinnate with 3 or 5 leaflets 4=leaves twice pinnate 5=leaves more than twice pinnate 6=leaves more than twice pinnate lance-shaped parts 7=leaves more than twice pinnate linear-shaped parts 8=leaves more than twice pinnate filiform-shaped parts
	Blade shape of the upper stem leaves	1 =Entire or slightly insected 2=Deeply incised with 3 lobes 3=once pinnate with 3 or 5 leaflets 4=leaves twice pinnate 5=leaves more than twice pinnate 6=leaves more than twice pinnate lance-shaped parts 7=leaves more than twice pinnate linear-shaped parts 8=leaves more than twice pinnate filiform-shaped parts
	Petiole color based on Monsoons color chart	1=pink 2=red
	Habit of the basal leaf	1=flat or prostrate 2=inclined (raised up to 45^0) 3=erect (inclined >45^0)
	Leaf color based on Monsoons color chart	1=deep green 2=light green
Generative	Anthocyanin in the petals	1= absent, if the petals are white in color 2= present, if the petals are pink or violet in color
	Shape of the fruits	1= round or even flattened 2=slightly lengthened 3= ovate

Wondo Genet Wondo Genet Agricultural Research Center were used for this study. Passport data for the accessions were given in Table 1. Seeds were directly drilled on rows on the prepared experimental units on July 15, 2008 at Kokate, and on July 18, 2008 at Wondo Genet. The experiment was conducted under rain fed condition. Two hoeing and three weddings were carried out and no fertilizer or other chemicals were applied. Samples were taken from the middle three rows leaving the two outer rows as borders. Five plants were considered for characters measured on individual plant basis. The whole plant was harvested when 50% of the plants on a plot turn brown. Harvesting was carried out early in the morning and late in the afternoon in order to minimize the fruit losses due to shattering. Then the whole plant was sun dried for some days and then threshed. The seeds were separated from the plant debris properly for the necessary measurements.

Data Collected: A total of 7 qualitative traits were recorded according to International Plant Genetic Resource Institute (IPGRI) to characterize and evaluate coriander accessions (Table 1).

Cluster Analysis: Recorded descriptors were subjected to Cluster analysis to determine common patterns of variation among groups of accessions with a matrix of distances correlation between traits means; the individuals were assorted in to discrete groups (Bahatt, 1969). Genetic divergences between clusters were calculated using the generalized Mahalanobi's D^2 statistics. The formula used was:

$$D^2p = (X_i - X_j)S^{-1} (X_i - X_j).$$

Where, D^2p=total generalized distance based on p characters.

X_i and $X_j$are the p mean vectors of accessions i and j, respectively.

S^{-1} = the inverse of the pooled covariance matrix.

The D^2 value obtained for pairs of clusters were considered as the calculated value of Chi-square (χ^2) and tested for significance 0.05 level of probability against the tabulated values of χ^2 for p degrees of freedom, where p is the number of traits considered (Singh and Chavdhury, 1985). SAS software program was employed for the analysis. The residual effect (U) implies the unexplained variation of the dependent variable that is not accounted by the path coefficient and it is calculated using the formula (Dewey and Lu, 1959) as:

$U=\sqrt{1-R^2}$, where $R^2 = \sum r_{ik}p_{kj}$

RESULT AND DISCUSSION

Variation in Qualitative Traits: Variability was observed for habit of the basal leaf, leaf color and anthocyanin in the petals. However, variability was not observed for leaf blade shape of the basal and upper stem leaves, petiole color and shape of the fruits. Variations in leaf habit, leaf color and anthocyanin in the petals are some of the traits that are used to distinguish between coriander accessions. Table 2 summarizes the data for the type of variation and distribution of accessions in terms of the 3 qualitative traits. The basal leaf angle ranged from flat, inclined to erect. The majority of the accessions (49%) had flat or prostrate leaf habits; whereas the remaining 30.6% and 20.4% had inclined and erect basal leaf habits, respectively.

Leaf

The largest proportions of the accessions had prostrate basal leaves. This finding is in agreement with studies at Gatersleben in Germany which indicated the habits of the basal leaves are usually more or less prostrate for all accessions (Diederichsen, 1996). According to Sil'enko (1981), the formation of a prostrate rosette basal leaf is a monogenic and recessive character, and plants with prostrate rosette leaves possess high frost resistance (Romanenko *et al*.,1990). This makes them suitable for sowing at any season of the year as long as other factors are not limiting. If the rosette is flattened, the vegetative cone is beneath the surface of the soil, and therefore has better protection against low temperatures (Romanenko *et al.,* 1991). These traits of basal leaf habits are easy to distinguish from one other, thus this feature is important for characterization of coriander.

The largest percentage of the studied accessions (57.14%) had deep green basal leaves while the remaining (42.86%) had light green basal leaves. These findings are in agreement with Rubatzskey *et al*. (1999) who also reported finding light and dark green basal leaves. This indicates that coriander can be further studied on the basis of basal leaf color as variation is clearly seen in Ethiopian accessions.

Blade shape of the lower basal leaves of the accessions under this study was characterized as once pinnate, with three to five leaflets and the upper stem leaves as more than twice pinnate filiform-shaped. A literature from a study at Gatersleben indicated that variation in longer basal leaf is an important morphological marker in coriander breeding (Diederichsen, 1996). The soviet breeding variety having an extreme pinnate basal leaf was found responsive in hybrid development (Gluenko and Sil'enko 1973; cited by Diederichsen, 1996). Extremely pinnated lower basal leaf bearing accessions are present in Belorussia and Kasachstan (Diederichsen, 1996). Therefore, leaf shape is very important for breeding and differentiations of coriander types grown worldwide.

The study revealed that all the accessions produced a green petiole. Both green and pink colored petioles can be found in Europe (Rubatzskey *et al*., 1999). However, coriander leaves with green petioles are preferred by the consumers in European countries as compared to pink petiole (Personal communication with the European peoples come to Ethiopia for short visit). Since, the coriander accessions bear the desirable petiole color, production of coriander as a leafy vegetable might have commercial potential in Ethiopia.

Flower

At Wondo Genet there was no variation in accessions flower color. All the accession produced white flower indicating the absence of anthocyanin in their petals. Likewise, three accessions taken from Ethiopia produced white flowers at Gatersleben (Diederichsen, 1996). However, at the Delbo watershed, 18.37% of the accessions produced pink flowers while the majority (81.63%) produced white flowers. This confirms that the production of anthocyanin by the coriander plant is both genetically and environmentally determined. Diederichsen (1996) clearly indicated that the ability to synthesize anthocyanin is obviously caused by the same gene, and to some degree is strengthened in its expression by environmental or physiological stress. Crossing experiments at Gatersleben showed that the ability of coriander to form anthocyanin is due to one dominant gene, as Romanenko (1990) had already noted for the petals of the plant and the mutation towards the recessive state, which causes white flowers. Therefore, this trait can be used as a morphological marker in coriander breeding that can be evaluated before generative stage.

Fruit

In this study, round fruit shape was observed for all the

Table 2. Variability of 49 Ethiopian coriander accessions on 3 qualitative traits tested at Kokate and Wondo Genet.

Character	Description	Frequency
Habit of the basal	Flat	49%
	Inclined	30.6%
	Erect	20.4%
Basal leaf color	Deep green	57.14%
	Light green	42.86%
Petal color	Pink	18.37%
	White	81.63%

accessions. In agreement with this study, Diederichsen (1996) also found round fruits from nearly all accessions studied at Gaterlisben. However, there are also other fruit shape types including lengthened and ovate fruits found in India and Pakistan, and completely globular fruit that are sometimes somewhat flattened found in Near Eastern types (Stoletova, 1990). Likewise, ovate coriander fruits have also been reported in Morocco (Hegi 1926; cited by Diederichsen, 1996).

Clustering

Quantitative traits were used as a data source for grouping of 49 accessions in to different clusters. SAS PROC GLM (2002) computer software was employed following the procedures of average linkage clustering analysis method. Genetic divergence between clusters was calculated using the generalized Mahalanobi's D^2 statistics.

Average clustering analysis based on the variability for leaf habits, leaf color and anthocyanin in the petals grouped the 49 accessions in to 7 clusters (Table 3 and Figure 1). In spite of absence of uniform relationships between quantitative and qualitative traits among accessions, there existed a sort of relationships between them (Beemnet*et al*., 2011). Clusters I and III in qualitative traits clustering share respective 50% and 57% of the characteristic features of cluster I of quantitative clustering. On the other hand, cluster II in quantitative clustering comprised 48.86% and 66.67% of the characteristic features of cluster IV and VII in qualitative clustering, respectively. Likewise, cluster II and VI in qualitative clustering share 52.38% and 66.67% of the characteristic features of cluster III in quantitative clustering, respectively. Moreover, cluster IV and V in qualitative clustering, comprised 42.8% and 50% of the characteristic features of cluster V and VI in quantitative clustering. Generally, deep green flat basal leaves had high seed yield and low oil contents. Light green erect basal leaves had low seed yield and high in oil content and inclined ones had intermediate values between the two. Therefore, benefits associated with the 3 qualitative traits can be exploited maximally by crossing the different clusters of wider genetic divergence (D^2) (Table 4).

The relationships between accessions in the same clusters were presented in Table 3. Accessions collected from varied altitudes Ethiopia were included in one cluster and distributed in different clusters sharing similar characteristics. This indicates the absence of geographic pattern and the accessions are disseminated to different locations through exchange of seeds or by other factors. Hence, the accessions were diversified indefinitely in different agro ecological conditions of the country. Therefore, intensive collection focusing on the desired traits will benefit breeders by large for effective improvement in coriander.

SUMMARY AND CONCLUSION

The study revealed that there were variations in phenotypic qualitative traits among accessions. More of the accessions have flat basal leaves followed by inclined and erect basal leaf habits.Corianders with prostrate basal leaves were less sensitive to frost damage and most of the studied accessions can be used for research and development activities in frost prone areas. Comparatively larger proportion of the genotypes had deep green basal leaves followed by accessions with light green basal leaves. This indicates that coriander can be further studied on the basis of leaf color. All the accessions had green petiole, which is more preferable for consumption as a leafy vegetable and contributes for market potential. Some of the accessions produced pink flower only in one of the testing locations showing the presence of anthocyanin that further indicated the dependency of accessions on the environment for the expression of anthocyanin.

Generally, deep green flat basal leaves had high seed yield and low oil contents. Light green erect basal leaves had low seed yield and high in oil content and inclined ones had intermediate values between the two. Therefore, benefits associated with the 3 qualitative traits can be exploited maximally by crossing the different clusters of wider genetic divergence (D^2). Accessions collected from varied altitudes Ethiopia were included in

Table 3. Clustering pattern, distribution and characteristic features of 49 Ethiopian coriander accessions based on 3 qualitative traits.

Cluster	Frequency	Accessions	Cluster characteristic features
I	6	90311, 203068, 205149, 207517, 219806, 223114	Erect light green basal leaves with white flowers.
II	21	203066,207515, 207519, 207520, 207973, 211471, 211473, 229711 , 230495, 230576, 230577, 235787, 240563, 240564, 240569, 240570, 240572, 240574, 240803,240805,222444	Flat basal leaves of them 62% are deep and (38%) light green in color all with white flowers.
III	7	207516, 207518, 208026, 223068, 223289, 240565, 242245	Inclined light green basal leaves with 3 white and 4 pink flowers
IV	7	207974, 212832, 229712, 240557, 240573, 242246, 242330	Inclined deep green basal leaves with white flowers.
V	2	229713, 235827	Inclined deep green basal leaves with pink flowers.
VI	3	211473, 240554, 240568	Flat deep green basal leaves with pink flowers.
VII	3	234051, 240804, 242243	Erect deep green with white flowers.

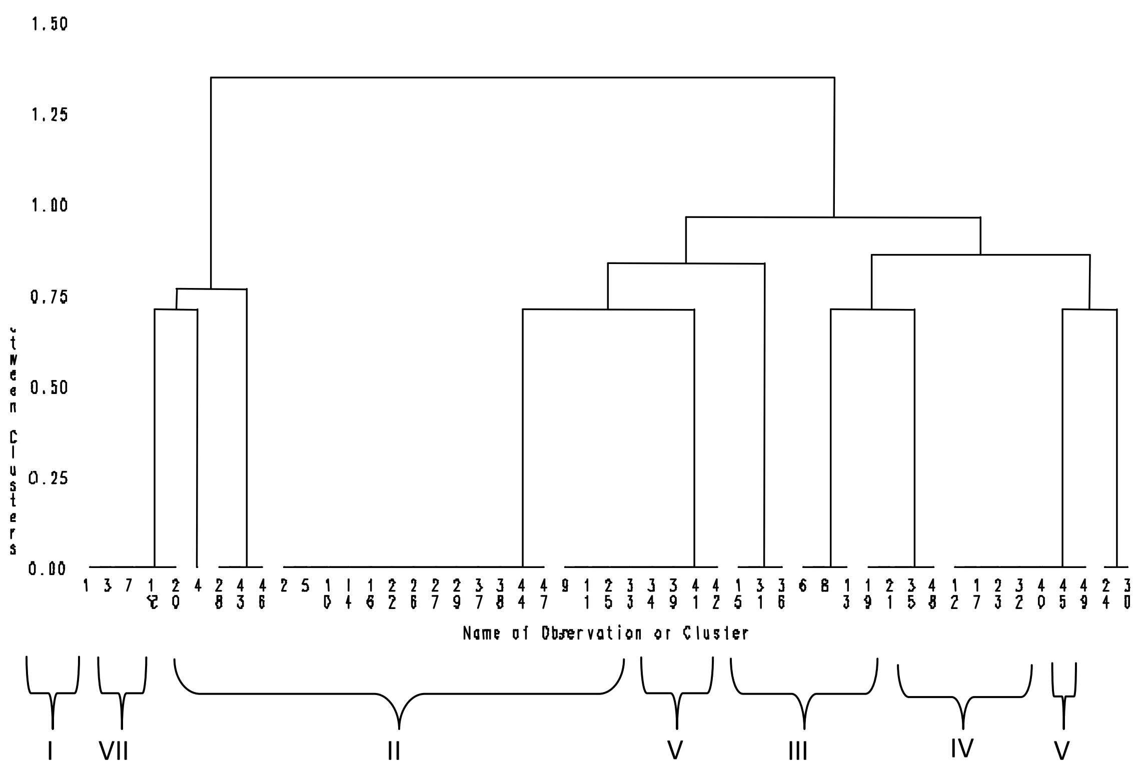

Figure 1. Dendrogram for qualitative traits of 49 coriander accessions

Table 4. Intra and inter cluster distance (D^2) in 49 accessions of coriander for 3 qualitative traits.

Cluster	I	II	III	IV	V	VI	VII
I	**4.2**	1557372673	389343172	389343180	389343193	1557372693	14.53
II		**1.70**	389343177	389343172	389343191	23.3	1557372675
III			**3.9**	15.4	20.26	389343186	389343184
IV				**3.9**	22.88	389343189	389343173
V					**6.4**	389343173	389343189
VI						**5.59**	1557372690
VII							**5.59**

χ^2 0.01, 3=11.34

one cluster and distributed in different clusters sharing similar characteristics. This indicates the absence of geographic pattern and the accessions are disseminated to different locations through exchange of seeds or by other factors. Hence, the accessions were diversified indefinitely in different agro ecological conditions of the country. Therefore, intensive collection focusing on the desired traits will benefit breeders by large for effective improvement in coriander.

As a conclusion remarks, despite Ethiopia is one of the center of primary diversity for coriander, diverse agro ecological conditions and market availability, coriander need not to be considered as one of the underutilized crops in Ethiopia. The study brought out the presence of substantial genetic variability for the important traits among accessions suggesting clue to improve the productivity of the crop through selection and breeding that enhance its cultivation. Still now many questions are remaining in coriander study like molecular and chemotaxonomic characterization, agronomic and breeding improvements. Moreover, the basic clue obtained in this study was drown from one year and two locations, testing of accessions on more locations and years are highly inquired.

ACKNOWLEDGMENTS

The financial assistance of Canadian International Development Agency (CIDA) and Universities Partnership Cooperation and Development (UPCD) project is sincerely acknowledged. Dr. Hussaien Mohammed, Mrs. Zewdinesh Damtew and Mr. Tewdros Mulualemare greatly acknowledged for the help in statistical analysis. We thank Birata Tilahun, Wondimu Manebo, Zerihun Jomba and Taddese Debele for their help in field work and laboratory analysis. Our acknowledgement also goes to Wondo Genet Agricultural Research Centre for all the necessary assistances. Equally, we extend our appreciation to NassaSabore for his willingness to provide the land for the research work at Kokate

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