ISSN 2286-4822
www.euacademic.org

EUROPEAN ACADEMIC RESEARCH
Vol. II, Issue 3/ June 2014

Impact Factor: 3.1 (UIF)
DRJI Value: 5.9 (B+)

Genetic Structure and Green Leaf Performance Evaluation of Geographically Diverse Population of Coriander (*Coriandrum Sativum* L.)

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Abstract:

Coriander (Coriandrum sativum L.) is an important leafy vegetable of family Umbelliferae with small fruits of great medicinal and nutritional value used as spice and condiment. As a marginal spice crop it is cultivated worldwide since centuries but its genetic diversity has rarely been documented. Present study was conducted to evaluate 69 coriander accessions from Pakistan, China, India and Iran for eight morphological characters i.e. number of days until start of flowering (DtFs), Number of days until end of flowering (DtFe), Number of days until harvesting (DtH), Number of days to stem elongation (DtSE), Plant height (cm), Length of longest basal leaf (cm), Number of basal leaves and 1000 fruit weight (grams). Data analyses revealed considerable genetic variability vis-à-vis eight agro-morphological parameters. Coefficient of variation (CV %) was higher for number of basal leaves (74.26), largest basal leaf length (33.89), plant height (33.24) and DtSE (22.42). Moderate variability was recorded for days to flower start (20.62) and 1000 seed weight (13.70). Pearson correlation revealed strong association between different traits i.e. days to start of flowering (DtFs) days to harvesting (DtH), number of basal leaves (NBL), length of basal leaves and 1000 seed weight had direct positive effect on each other. Hierarchical cluster analysis was

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performed using Ward's method which classified all genotypes within 4 major groups. Clustering pattern of accessions was synchronized with morphological characters of the genotypes instead of geographical origin of the accessions. However non-local accessions like Chinese, Indian and Iranian grouped together in cluster IV.

Key words: Coriander; Morphological characters; Genetic diversity; green leaf.

Introduction

Coriander (*Coriandrum sativum* L.) is an annual *Apiaceae* herb mostly grown for its leaves and seed fruit as spice and condiment. It is an important member of *Umbelliferae* family having 2n=22 chromosomes and mostly considered native to Mediterranean basin. It is cultivated throughout the world for its aromatic leaves and spicy seed due to its wide adaptation to range of eco-geographic conditions (Purseglove *et al*, 1981; Simon 1990). It is leafy vegetable rich in vitamins, proteins and dietary elements while seed fruit contains 13-29% vegetable oil (petroselinic acid) and 0.35% essential i.e. linalool (Diederichsen, 1996; Ramadan and Mörsel, 2002; Singh *et al.*, 2003; Msaada *et al.*, 2007).

Coriander is considered important herb due to its extensive use as medicine for curing capabilities against many diseases due to presence of active ingredients in its leaves and fruit (Kubo *et al.*, 2004). Most importantly it is well known for its fraction of volatile essential oil composition like terpenoids and phenolic constituents which are of great importance in the field of pharmacology (Sriti *et al*, 2013). In addition, its oil also contains different antioxidants, anticancer, antibacterial and anti-mutagenic agents as trace compounds (Mataysoh *et al.*, 2009). In literature multiple medicinal uses of coriander have been reported by authors such as antifertility agent (Al-Said *et al.*, 1987), hypotensive (Burdock and Carabin, 2008), antihyperlipidermic (Chithra and Leelamma, 1999), anti-hyperglycemic (Eidi *et al.*, 2009), anti-proliferative (Nakano *et al.*, 1998) and as a digestive stimulant (Platel and Srinivasan, 2000).

Coriander seeds, for which it is mainly grown throughout the world, are used in different ways i.e. as a food in different regions of the world as well as in perfume and cosmetics industries due its pleasant smell and aroma. Its oil is among the world top 20 important and significant oils (Lawrence 1992), having different grads commercially due to differences found in its properties and fragrance (Smallfield *et al.*, 2001). The highest amount of essential oil contents reported is up to 2.7 percent while its lower value found up to 0.03 percent of the dried fruits (Bandara *et al.*, 2000).

Due to its great agronomic and medicinal value, it is very important to fully explore the genetic diversity found among the present day germplasm of coriander for identification of elite high yielding, vegetatively prolific and vigorous plant for further utilization in future breeding programs. In every crop, presence of adequate amount of genetic diversity is not only important for survival of that plant species against drastic environmental conditions, climatic changes and stresses but it is also considered as a pre-requisite for development of the improved cultivars with enhanced nutritional and agronomic value (Mohammedi and Prasanna 2003; Khurshid and Rabbani, 2012). Recently, authors have studied availability of genetic diversity using agro-morphological characterization in coriander from diverse ecologies and reported significant magnitude of phenotypic and phonological variation in the germplasm (Lo´pez *et al*, 2008; Mengesha *et al.*, 2011; Fufa 2013). In coriander, Leaf performance has also been the focus of curators due to its significant importance as vegetable. Consequently studies have been conducted to evaluate leaf potential (Bashtanova and Flowers, 2011; Chaulagain *et al*, 2011) in local and international coriander germplasm as per Diederichsen's (1996) descriptor.

The present study was also aimed to quantify variability in the genetic makeup of coriander germplasm from Pakistan and its neighbors i.e. China, India and Iran using agro-morphological characters and also to estimate green leaf production potential of these genotypes.

Materials and Methods

The experiment was carried out at Plant Genetic Resources Institute (PGRI), National Agricultural Research Centre (NARC), Islamabad, Pakistan (33° 33' N and 73° 06'E) during 2012-2013. The average annual rainfall in the area differs from 500mm to 900mm, which is 70% during summer season and 30% during winter. Sixty nine coriander accessions from Pakistan, China, India and Iran were obtained from the gene bank of PGRI and planted in augmented design at field where each accession was planted in a single row of 3 meter. The distance between plants with in a row was 20cm while row to row distance was kept at 40 cm.

For all accessions, data was recorded for 3 randomly selected plants within each line against eight (8) agronomically important traits i.e. Number of days until start of flowering (DtFs), Number of days until end of flowering (DtFe), Number of days until harvesting (DtH), Number of days to stem elongation (DtSE), Plant height (cm), Length of longest basal leaf (cm), Number of basal leaves and 1000 fruit weight (grams). The trait selection and data recording was carried out according to the IPGRI descriptor developed by Diederichsen (1996).

Data Analysis

Descriptive statistics analyses was performed on the data for all traits to compute mean, minimum and maximum value, coefficient of variance (CV %) and standard deviation using MS Excel 2010. Also, STATISTICA 10.01 software package (StatSoft, Inc.) was used to generate dendrogram based on Ward's method of hierarchical cluster analysis for mean values of all agro-morphological traits.

Table 1: list of accessions evaluated for 8 morphological parameters.

S.NO.	Accession	Country	S.NO.	Accession	Country	S.NO.	Accession	Country
1	10245	Local	25	20102	Local	49	27048	Local
2	10329	Local	26	20107	Local	50	27049	Local
3	10500	Local	27	20120	Local	51	27050	Local
4	10507	Local	28	20129	Local	52	27051	Local
5	10525	Local	29	20149	Local	53	27052	Local
6	10529	Local	30	20150	Local	54	27053	Local
7	20166	Local	31	20161	Local	55	27054	Local
8	10705	Local	32	20199	Local	56	27055	Local
9	10775	Local	33	20206	Local	57	27056	Local
10	10788	Local	34	20220	Local	58	27057	Local
11	10823	Local	35	20225	Local	59	27058	Local
12	10826	Local	36	20226	Local	60	27059	Local
13	10882	Local	37	20275	Local	61	27068	China
14	19441	Local	38	20312	Local	62	27060	Iran
15	19442	Local	39	20331	Local	63	27065	India
16	19443	Local	40	20346	Local	64	27062	Local
17	19454	Local	41	20383	Local	65	27063	Local
18	19444	Local	42	20384	Local	66	27064	Local
19	19447	Local	43	20403	Local	67	27066	Local
20	19446	Local	44	20417	Local	68	27067	India
21	19240	Local	45	20431	Local	69	27061	Iran
22	19241	Local	46	20486	Local			
23	20070	Local	47	20489	Local			
24	20083	Local	48	20504	Local			

Results

For eight agro-morphological traits data recorded revealed sufficient level of phenotypic variation among all the genotypes.

Leaf related traits i.e. number of basal leaves and largest basal leaf length were highly variable followed by plant height, days to stem elongation and days to flower start. Coefficient of variance was higher for number of basal leaves (74.26), largest basal leaf length (33.89), plant height (33.24) and Days to stem elonngation (22.42) (Table 2). Moderate variability was recorded for days to flower start (20.62) and 1000 seed weight (13.70) but days to flower completion and vegetative maturity were found to be less variable among the accessions. Maximum 23 basal leaves were recorded in local accessions 10775, 10788, 10826 and 19454 while accessions 10525, 10823, 10826, 19441, 19443 and 19454 had longest basal leaves (26 cm). Plant height ranged from 63cm in accession 27062 to maximum 341cm in 20312. Accessions 27053, 27054, 27055 and 27056 were earliest at maturity by taking minimum of 176 days against late maturing genotypes e.g. 19441, 19442, 19443 which took 200 days till harvesting. Shortest flowering duration was recorded for 20431, 27049, 20486, 27055 and 27056 with 132, 134, 135, 135, and 136 days to flower completion respectively. Days to stem elongation were recorded maximum 177 for accession 20161 followed by Chinese accession 27068; while 2 local (27063, 27064) and one Indian accession (27067) were found to be earliest at stem elongation and took only 86 days to elongate. As an important yield and seed attribute maximum 1000 seed weight (9.25g) was recorded for local accessions 10329 and 19240 followed by Chinese origin accession 27068 (8.37g) and Iranian ecotype 27061 (8.28g) and 27060 (8.25g).

Table 2: Basic statistics of studied traits.

Trait	Mean± SD	Range	CV (%)
Number of days until start of flowering (DtFs)	120.014±24.743	98-285.4	20.62
Number of days until end of flowering (DtFe)	150.930±9.971	132-182.6	6.61
Number of days until harvesting (DtH)	187.081±8.124	176-200	4.34
Days to Stem Elongation (DtSE)	104.212±23.366	86-177	22.42
Plant height (cm)	106.101±35.273	63-341.6	33.24
Length of longest basal leaf	15.342±5.20	8.6-26.6	33.89
Number of basal leaves	8.852±6.574	3-23.2	74.26

1000 fruit weight (grams)	7.078±0.969	5.72-9.25	13.70

Pearson Correlation

Correlation matrices depicted strong association among different agronomic traits (Table 3). Days to flower initiation were positively correlated to days to harvesting, number of basal leaves, length of basal leaves and 1000 seed weight. Flowering duration was significantly positively correlated to days to harvesting, length of basal leaves and 1000 seed weight but had negative correlation vis-à-vis plant height. Positive correlation was observed between days to harvesting and number of basal leaves, length of basal leaves and days to stem elongation. Highly significant positive association was found between number of basal leaves and length of basal leaves. Negative correlation was observed between plant height and number of basal leaves. Days to stem elongation had positive association with number of basal leaves and plant height.

Table 3: Cluster distribution of studied genotypes.

Traits	Cluster I Genotypes 24	Cluster II Genotypes 21	Cluster III Genotypes 18	Cluster IV Genotypes 6
Number of days until start of flowering (DtFs)	112	108	138	142
Number of days until end of flowering (DtFe)	148	146	154	170
Number of days until harvesting (DtH)	183	182	197	193
Days to Stem Elongation (DtSE)	101	95	110	131
Plant height (PH)	108.76	102.42	97.3	134.77
Length of longest basal leaf (LBL)	13.24	12	22.58	13.73
Number of basal leaves (NBL)	6	4	19	7
1000 fruit weight (grams)	7.82	6.33	6.77	7.63

Cluster Analysis

A dendrogram was generated using ward's method of hierarchical cluster analysis which distributed all 69 genotypes in four major groups at 12% linkage dissimilarity level on the basis of 8 agro-morphological parameters (**Figure 1**). First group was largest which accounted for 34.78% of the overall population having 24 local accessions. These genotypes were attributed as medium heighted with healthiest fruit i.e. maximum 1000 seed weight (7.82g). Second group comprised of 21 genotypes including one Indian accession which represented

30.43% of the population. These genotypes were regarded as earliest at flower initiation (108 days), flower completion (146 days), days to harvesting (142 days) and days to stem elongation (95 days). Number of basal leaves (4) and length of basal leaves (12cm) and 1000 seed weight (6.33g) were also recorded minimum for these genotypes. Third cluster had 18 accessions (26.09%) all local with shortest height (mean 97.3cm) and maximum mean number of days to harvesting (197). besides all individuals in this group were best at leaf performance as maximum mean number of basal leaves (19) with maximum mean length (22.58cm) was observed for these accessions. Fourth group consisted of 6 genotypes including two local one Indian, one Chinese and 2 Iranian accessions. All these genotypes had maximum mean height (134.77cm), which also took maximum number of days to flower initiation (142), days to flower completion (170) and days to stem elongation (131).

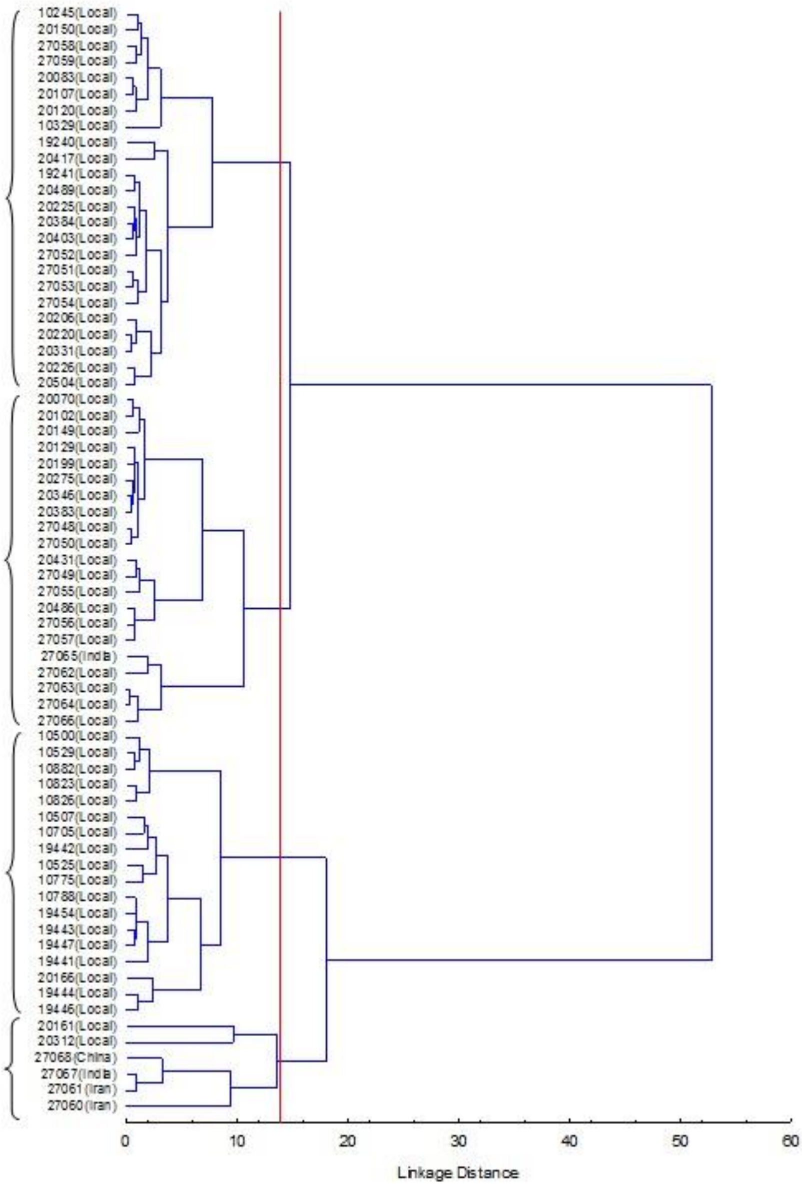

Figure 1: Dendrogram of the studied genotypes.

Discussion

Morphological characterization is important for assessment of genetic potential of plant germplasm and its further utilization for crop improvement. Chaulagain *et al*., (2011) studied green leaf performance in ten coriander (*Coriandrum sativum* L.) genotypes under late sowing conditions and observed agronomic characters i.e. plant height, rosette diameter, length of the longest basal leaf, total number of leaves, number of basal leaves, number of pinnatifid leaves and number of decompound leaves. Fufa (2013) evaluated genetic divergence in 25 coriander accessions using 8 agronomic traits as per IPGRI descriptor and confirmed presence of considerable genetic diversity in the available gene pool of the plant. We also, in the present study reported phenotypic and phonological variation in coriander germplasm for leaf and vegetatively important attributes from Asian origin i.e. Pakistani, Indian Iranian and Chinese accessions. Our results revealed significant genetic divergence in coriander germplasm for important traits i.e. number of basal leaves, largest basal leaf length, plant height, days to stem elongation and days to flowering initiation which is in accordance with the results of Singh *et al*, (2005) who observed substantial amount of diversity for various morphological characters in the crop. Mengesha *et al*., (2011) also examined genetic variation in 49 Ethiopian coriander accessions for 15 qualitative and quantitative traits of economic importance and suggested availability of ample genetic diversity for utilization in crop improvement and breeding programs. Leaf performance was considered chief among other agronomic traits due to its increased use as vegetable and salad, locally. We observed higher degree of variability in leaf related traits e.g. number of basal leaves and length of largest basal leaf which signified importance of these parameters as prominent descriptors for genetic diversity examination in coriander population. Our results were supported by previous findings of Fufa (2013) who concluded from principal component analysis of eight morphological traits in coriander that maximum genetic variation was contributed mainly by length of basal leaves and foliation. Mengesha *et al.*, (2011) observed strong role of seed yield, number of basal leaves and plant height towards genetic variability of the coriander which was further confirmed by our results. Therefore inclusion of these traits as criterion for the selection of superior genotypes and assessment of genetic structure of the coriander is strongly suggested.

Pearson correlation studies divulged direct and strong relationship between different agro-morphological traits like days to start of flowering (DtFs) days to harvesting (DtH), number of basal leaves (NBL), length of basal leaves and 1000 fruit weight had direct positive effect on each other. These associations between agronomic parameters is in complete agreement with the results of Lopez *et al*, (2008) which confirmed strong positive correlation between different morphological and phonological traits in coriander in their study of genetic diversity assessment through agronomic traits biochemical and AFLP markers. Though authors have cautioned that correlation may not be causal (Sokal and Rohlf, 1995) however it is possible that selection of genotypes for traits i.e. maximum number of days to flowering start (DtFs) and harvesting (DtH) and shorter height (PH) may possibly lead to increased number of basal leaves (NBL) and higher fruit yield. Likewise we reported direct positive effect of number of basal leaves and plant height on 1000 fruit weight which was earlier reported by Kassahun *et al* (2013).the pattern of positive correlation observed between different phonological and agronomic traits of coriander accessions in our studies were in complete agreement with previous studies in coriander (Bahandari and Gupta, 1991; Tripathi *et al*, 2000; Lo´pez *et al*, 2008).

Clustering of genotypes in 4 groups was mainly synchronized with the 8 agronomic characters. Days to flowering start, flowering duration, plant height, number and length of basal leaves and 1000 fruit weight performance were strong factors for distributing accessions among their respective clusters. Lo´pez *et al* (2008) also reported clustering arrangement of coriander accessions solely on the basis of agro-morphological traits i.e. number of basal leaves, length of basal leaves, plant height and 1000 fruit weight etc. Geographical distribution was not a strong determinant of clustering pattern among the germplasm though all non-Pakistani accessions i.e. Chinese, Iranian and Indian mainly clustered closely in cluster IV, except one Indian accession (27065) which grouped with local accessions in cluster II. Here again our results were in accordance with those of Lopez *et al* (2008) which found no linkage between geographic origin of the coriander accessions and their position in cluster analysis dendrogram. Similarly, Ghafoor and Ahmad (2005) have confirmed that distribution of genotypes in dendrogram could be independent of its geographic origin as he found no association between origin and clustering of black gram genotypes from diverse ecologies.

In the present study, distribution of local (Pakistani) accessions so closely in larger groups is testament to the existence of narrow genetic base of the local coriander germplasm. Therefore it necessitates for curators and gene bank managers to introduce exotic genetic resources from international gene banks in order to broaden available gene pool of the crop. However we investigated extent of phenotypic and phonological variation among local and foreign coriander accessions and observed ample variability for important traits related to flowering duration, leaf production and fruit yield. All these traits were found to be inter-linked to each other and signified importance of these characters to be used as criterion while selecting elite lines and parents for utilization in breeding programs. Nonetheless, it is suggested that newer techniques of biochemical and molecular analysis should also be employed to assess genetic divergence at intraspecific level.

Acknowledgement:

The authors acknowledge the contribution of Gene bank of Plant Genetic Resources Institute, National Agricultural Research Center, Islamabad-Pakistan for providing coriander germplasm, field facility and services.

REFERENCES

Al-Said, M.S., K.I. Al-Khamis, M.W. Islam, N.S. Parmar, M. Tariq and A.M. Ageel. 1987. "Post-coital antifertility activity of the seeds of Coriandrum sativum in rats." *J. Ethnopharmacol*. 21: 165-73.

Bahandari, M. and Gupta, A. 1991. "Variation and association analysis in coriander." *Euphytica* 58:1-4.

Bandara, M., C. Wildschut, E. Russel, L. Ost, T. Simo and J. Weber. 2000. "Special crops program (Brooks). Alberta, Agriculture, Food, and Rural Development." *Crop Diversification*. P. 41.

Bhandari, M.M. and A. Gupta, 1991. "Variation and association analysis in coriander." *Euphytica* 58: 1-4.

Burdock, G.A. and I.G. Carabin. 2008. "Safety assessment of coriander (Coriandrum sativum L.) essential oil as a food ingredient." *Food Chem. Toxicol*. 47: 22-34.

Chaulagain, R., S.S. Pant, R.B. Thapa and M. D. Sharma. 2011. "Performance of coriander cultivars for green leaf production under late sowing condition." *The Journal of Agriculture and Environment*. 12: 67-73.

Chithra, V. and S. Leelamma. 1999. "Coriandrum sativum changes the levels of lipid peroxides and activity of antioxidant enzymes in experimental animals." *Ind. J. Biochem. Biophys*. 36: 59-61.

Diederichsen, A. 1996. *Coriander (Corianderum sativum L). Promoting the conservation and use of underutilised and neglected crops. 3.* Institute of Plant Genetics and Crop Plant Research, Gaterslbebn / International Plant Genetic Resources Institute, Rome, Italy. 83pp.

Eidi, M., A. Eidi, A. Saeidi, S. Molanaei, A. Sadeghipour, M. Bahar and K. Bahar. 2009. "Genetic performance and maximizing genetic gain Effect of Coriander seed (Coriandrum sativum L.) ethanol extract on insulin release from pancreatic beta oak cells in Streptozotocin induced diabetic rats."

Emamghoreishi, M., Khasaki, M. and M.F. Aazam. 2005. "Coriandrum sativum: evaluation of its anxiolytic effect in the elevated plus-maze." *J. Ethnopharmacol.* 96: 365–370.

Fufa, M. 2013. "Genetic Divergence in Ethiopian Coriander (Coriandrum sativum l.)." *Adv Crop Sci Tech.* 1 (4): 116.

Ghafoor, A. and Z. Ahmad. 2005. "Diversity of agronomic traits and total seed protein in black gram Vigna mungo (L.) Hepper." *Acta biologica cracoviensia.* Series Botanica. 47/2: 69–75.

Kassahun, B. M., Getinet, A. and B. Tesfaye. 2013. "Correlation Studies and Path Coefficient Analysis for Seed Yield and Yield Components in Ethiopian Coriander Accessions." *African Crop Science Journal.* 21(1): 51 – 59.

Khurshid, H., Rabbani, M.A. 2012. "Comparison of Electrophoretic Protein Profiles from Seed of Different Oilseed *Brassica* Cultivars." *J.P.H. and Bio. Sci.* 1(2): 36-42.

Kubo, I., Fujita, K., Kubo, A., Nihei, K. and T, Ogura. 2004. "Antibacterial activity of coriander volatile compounds against Salmonella choleraesuis." *Journal of Agriculture and Food Chemistry.* 52(11): 3329-3332.

Lawrence, B.M. 1992. "A planning scheme to evaluate new aromatic plants for the flavor and fragrance industries."

In *Proceedings of the Second National Symposium. New Crops: exploration, research, and commercialization*, edited by J. Janick and J.E. Simon, 620-627. New York: John Wiley and Sons, Inc.

Lopez, P.A., Mark, P. Widrlechner, P, Simon W., Satish, R, Terri, D. Boylston, Terry, A. Isbell, Theodore B., Bailey, Candice, A. Gardner, Lester, A. and Wilson. 2008. “Assessing phenotypic, biochemical, and molecular diversity in coriander (Coriandrum sativum L.) germplasm.” *Genet Resour Crop Evol*. 55:247–275.

Maghrani, M., Zeggwagh, N.A., Haloui, M., Eddouks, M. 2005. “Acute diuretic effect of aqueous extract of Retama raetam in normal rats.” *Journal of Ethnopharmacology*. 99: 31–35.

Mataysoh, J.C., Z.C. Maiyo, R.M. Ngure and R. Chepkorir. 2009. “Chemical composition and antimicrobial activity of the essential oil of Coriandrum sativum.” *Food Chem*. 113: 526-529.

Mengesha, B., G. Alemaw, B. Tesfaye. 2011. “Genetic divergence in Ethipian coriander accessions and its implication in breeding of desired plant types.” *African Crop Science Journal* 19 (1): 39-47.

Mohammedi, S.A., and Prasanna. B.M. 2003. “Analysis of genetic diversity in crop plants-salient statistical tools.” *Crop. Sci*. 43: 1235-1248.

Msaada, K., K. Hosni, M. B. Taarit, T. Chahed, M. E. Kchouk, and B. Marzouk. 2007. “Changes on essential oil composition of coriander (Coriandrum sativum L.) fruits during three stages of maturity.” *Food Chemistry* 102(4): 1131–1134.

Msaada, K., Hosni, K., Taarit, M.B., Chahed, T., Kchouk, M. E., and B. Marzouk. 2007. “Changes on essential oil composition of coriander (Coriandrum sativum L.) fruits during three stages of maturity.” *Food Chemistry* 102(4): 1131–1134.

Nakano, Y., H. Matsunaga, T. Saita, M. Mori, M. Katano and H. Okabe. 1998. "Antiproliferative constituents in Umbelliferae plants II. Screening for polyacetylenes in some Umbelliferae plants and isolation of panaxynol and falcarindiol from the root of Heracleum moellendorffii." *Biol. Pharm. Bull.* 21: 257-61.

Platel, K. and K. Srinivasan. 2000. "Stimulatory influence of select spices on bile secretion in rats." *Nutr. Res.* 20(10): 1439-1503.

Purseglove, J.W., Brown, E.G., Green, C.L. and S.R.J. Robbins. 1981. *Spices*, vol. 2. New York: Longman. 736–788.

Ramadan, M.F. and J.T. Mörsel. 2002. "Oil composition of coriander (Coriandrum sativum L.) fruit-seeds." *European Food Research and Technology* 215(3): 204–209.

Said, H.M., Saeed, A., D'Silva, L.A., Zubairy, H.N. and Z. Bano.1996. *Medicinal Herbal: A Textbook for Medical Students and Doctors*. Vol. 1. Pakistan: Hamdard Foundation Pakistan. pp. 1–82.

Simon, J.E.1990. "Essential oils and culinary herbs." In *Advances in new crops. Proceedings of the First National Symposium. New crops: research, development, economics,* edited by J. Janick and J.E. Simon, 472–483. Portland, Oregon: Timber Press.

Singh, H.B., Singh, A., Tripathi, A., Rai, S.K., Katiyar, R.S., Johri, J.K., and S.P. Singh. 2003. "Evaluation of coriander germplasms for stem gall disease." *Genet. Resource and crop Evolution.* 50 (4): 339-343.

Singh, S.P., Katiyar, R.S., Rai, S.K., Tripayhi, S.M., and J.P. Srivastava. 2005. "Genetic divergence and its implication in breeding of desired plant type in coriander (Coriandrum sativum L.)." *Genetika* 37(2):155-163.

Smallfield, B.M., Klink, J.W.V., Perry, N.B. and G. Dodds. 2001. "Coriander spice oil: effects of fruit crushing and distillation time on yield and composition." *Journal of Agricultural and Food Chemistry*. 49: 118-123.

Sokal, R. R. and F. J. Rohlf. 1995. *Biometry; The principles and practice of statistics in biological research*. 3rd ed. New York: W. H. Freeman and Company.

Sriti, Jazia, Manel Neffati, Kamel Msaada, Thierry Talou and Brahim Marzouk. 2013. "Biochemical Characterization of Coriander Cakes Obtained by Extrusion." *Journal of Chemistry*. 2013: 1-6.

Tripathi, S.M., Srivasttava, S.B.L. and J.P. Srivastava. 2000. "Variability, heritability and correlation studies in coriander (Coriandrum sativum L.)." Central conference on spices and aromatic plants, 20-23 September, 2000. Calicut, Kerala, India.